ENGINEERING

OF

SHOPS AND FACTORIES

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BY

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PREFACE

This book is based upon the writer's personal observations, study and experience, covering a period of more than twenty years in this line of work. It is a sequel, and supplementary to his other book entitled "Mill Buildings," and, excepting in a few cases, parts which are fully treated there are not repeated here. Additional information and costs on some subjects have been included, which have come to his attention since his last book was published.

Chapter I., entitled "Industrial Engineers and Their Services," should be valuable both to engineers and factory owners, because it gives the standard rules of conduct and business which have been established and accepted by several of the leading engineering societies. Similar rules have long existed, governing the relations between architects and contractors. The chapters on the economics of factory location and construction are included, because of the enormous amount of money being invested in manufacturing industries. If these plants are, at first, wrongly placed or arranged, no amount of subsequent good management can remedy the initial mistakes. Several chapters are included on concrete buildings and their cost, because of the increasing use of this material, and much of the objection to the type should be removed by the explanation of easy and effective methods of surface treatment to give them a more attractive appearance. Such details as foundations, walls, roofing, etc., which are fully treated in the author's book entitled "Mill Buildings," are mentioned only briefly here, that space may be left for other subjects.

Several chapters originally contributed by the writer to the *Engineering Magazine*, are reproduced with little or no change. In order to make the book of greater value, some of the chapters have been prepared with the aid of specialists, most of the material on Heating and Air Washing being supplied by the Buffalo Forge Company, and that on Artificial Lighting by the Westinghouse Electric Company. Many of the illustrations are from the pages

of *Engineering News*, *Engineering Record*, *Railway Age Gazette* and other journals.

The book is designed to aid all who are interested in shops and factories, and especially engineers, architects, draftsmen and students, as well as factory owners and employees.

H. G. Tyrrell.

Evanston, Illinois.
October, 1912.

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INTRODUCTION

The building of shops and factories has developed in the last few years into one of the largest branches of modern business. Those who were formerly content to carry on manufacturing in shops of the old type have long since discovered that the buildings themselves can be made one of the largest factors in economic production, and more adequate ones are everywhere in evidence. Goods of great value were formerly made and stored in buildings which were improperly lighted, heated and ventilated, and liable at any time to be destroyed by fire. As a partial protection against loss, heavy insurance was often carried, with a corresponding charge against the business. From inadequate ventilation, the building interiors were often smoky and dusty, and valuable goods were in constant danger of being soiled. In many cities and districts, especially where soft coal was used for fuel, the atmosphere was loaded with smoke, and the depreciation of goods was often a serious loss.

The planning and arranging of plants was formerly done by their owners or managers, who made little or no provision for their extension or development, and who considered that business success depended wholly upon good management. It was then the belief that the buildings were of little importance, but it is now well known that they can and should be arranged and designed to facilitate production to the greatest extent. As the building of plants has increased, and steel and concrete have, to a large extent, replaced wood as a structural material, the assistance of engineers and architects have been sought, not only in planning the buildings, but in installing and arranging their equipment. Business in this direction has increased to such an extent as to give employment to a large number of men known as Industrial Engineers, who are especially trained in the planning and building of shops and factories. These men, giving special study to the economics of manufacturing plants both as to construction and operation, are frequently able in addition to other services, to give valuable advice and assistance to owners.

Enterprises have usually begun in rented space or in small buildings owned by their occupants, and extensions are generally the outcome of small beginnings. New shops may consist of additions to old plants, or entirely new buildings may be erected on a more commodious site, the latter method giving the largest opportunity for economic design and arrangement. The efficiency of a new plant, or its capability of producing at minimum cost, depends to a great extent on the thought and study which has been given to shop economics, previous to the beginning of building operations. Efficiency is greatly hindered when a building is unsuited to its use, and defects which are discovered after completion are usually too expensive to remedy. The need is, therefore, evident for very careful planning and study before beginning the detail drawings, and such investigations are by far the most important part of the engineer's work. The building should be considered merely as a part of one great industrial machine, the various men and tools all fulfilling their respective duties, and working harmoniously together with the greatest efficiency and the least total cost.

To have any prospects of successful operation, amid present industrial competition, a plant must be in an advantageous district, must be economically designed and well arranged, and have low maintenance cost. When these ends are attained, its further success will depend upon good judgment and careful buying, combined with other established principles of business, such as reputation for honesty and fair dealing.

The extent and importance of manufacturing industries can best be appreciated by a consideration of the following approximate data relating to the whole United States.

Number of manufacturies	240,000
Capital invested	$21,000,000,000
Number of employees	7,000,000
Wages earned per year	$ 4,000,000,000
Value of materials used	$18,000,000,000
Value of products	$30,000,000,000

The approximate costs given throughout the book apply only to the conditions given, and will change according to the time and place and with the local rate of wages and the cost of building supplies. Prices in the Northern States are quite different to those in the Southern and Western States, and may hardly

approximate those obtainable in other countries. They must, therefore, be used with great caution, for otherwise they may lead to serious errors. When estimating costs, the engineer should familiarize himself with prices and conditions in the district where goods and labor must be purchased.

ENGINEERING OF SHOPS AND FACTORIES

CHAPTER I

ENGINEERS AND THEIR SERVICES

Building Plans. *By Whom Made.*—When a company has decided to erect new buildings or extensions, the work is usually wanted in the shortest time possible. One of the first duties of the company will be the selection of one or more men to work out the plans. This work is sometimes divided between two men or sets of men, the first being mechanical or plant engineers and the others, structural engineers, each group of men being trained in a special line of work. In other cases the whole work is undertaken by one engineer or engineering firm. When a plant engineer is first employed, it is his duty to investigate all matters pertaining to the arrangement of machinery and departments, and to carry on preliminary studies as outlined in Chapters II and III, under the direction of, and in consultation with the plant owners. He will, in fact, outline the whole scheme and furnish the structural engineer with preliminary plans and approximate cost estimates. (See Tyrrell's Mill Buildings, page 12.) This greatly simplifies work for the structural engineer, as his duties then relate chiefly to matters of building construction and economic design.

When the whole work of planning a plant, including the preliminary, mechanical and constructive details is entrusted to one man or firm, the duties of the engineer are greatly enlarged and it is this condition which is assumed in the following discussion.

When looking about for persons to make investigations and prepare designs and drawings, the plant owner usually finds that this work may be done in at least four different ways.

1. By the company's draftsmen under the direction of the owner.

2. By the company's draftsmen under the supervision of a specially employed industrial engineer.

3. By a contracting firm expecting to secure a contract for construction.

4. By a consulting engineer or firm, with staff assistance.

1. The first of these methods often appears to owners to be the cheapest and most attractive, for plans would then be obtained at cost price. The disadvantage is, that shop draftsmen accustomed to working on machinery parts, are, as a rule, unfamiliar with building construction, and the owner or manager who may be thoroughly familiar with manufacturing methods and works management, even though he may in earlier years have been an expert draftsman, no longer has time to keep himself informed on such matters. Another disadvantage of this method is that the owner and his drafting force are not in possession of data pertaining to manufacturing plants in general, and their time is too fully occupied with other duties to permit them to concentrate thought on this important work. The successful manager of a woolen mill would certainly not attempt to manufacture the machinery for his mill, and for the same reason he can hardly be expected to proficiently design the details of factory building.

2. The second method of securing plans, in which the owner employs an industrial engineer to work out the designs and drawings with the assistance of the plant draftsmen, is unsatisfactory for the same reason as stated before, that such men are rarely familiar with structural work or building construction. If special draftsmen are employed under the direction of an industrial engineer, the result is practically the same as when a consulting engineer or firm is employed, for, if proficient, he will expect responsible charge. If he is not thoroughly proficient and is willing to give his services for little more than draftsmen receive, it is hardly probable that a works manager would, on second thought, be willing to entrust him with the planning of buildings involving the expenditure of a large sum of money. The law of economic construction should be remembered, which is—that in the building of plants, the greatest efficiency and economy are obtained only when the work is under the direction of a thoroughly proficient and experienced person.

3. The acceptance by an owner of a competitive design (Fig. 1) from a firm hoping to receive a contract for the work, is questionable practice and often unsatisfactory. Contractors who make a practice of getting work in this way, expecting to secure only part—perhaps one-fifth—of all work for which they make plans, must add to each bid, the cost of making plans for the other four-fifths. Therefore, instead of paying for one set of

plans, the owner must really pay for at least five sets, with a possible increase to ten or more, if the contractor is successful in a less number of cases. To compensate for this contracting expense, and yet keep the cost down to what it would be if there was only one set of plans to pay for, the contractor must use cheaper or lighter material, with a corresponding reduction in strength. On the other hand, if the owner receives plans from only one contractor and awards a contract on a unit or tonnage basis, he may then be obliged to pay for extra weight or material. A structural company for which the writer was engineer, once received a contract for several large steel frame buildings on a

Fig. 1.—Factory building for Scott & Bowne, Bloomfield, N. J.

tonnage basis, and instead of supplying the purchaser with a rational design, the proprietors of the structural company insisted on using excess material to such an extent that riveted steel columns were made of plates and angles $\frac{5}{8}$ in. thick, when $\frac{5}{16}$-in. thickness was sufficient, with corresponding waste in other parts.

A better way of securing plans is to employ a competent and conscientious structural engineer whose only object will be to serve the best interests of his client. The owner should then get the best results that are obtainable and pay only for service which he receives. Better results usually follow by leaving details of

construction to the engineer, who is better qualified than the owner to make such selection. The employment of a consulting engineer may result in a larger amount of money being paid for engineering service, than if such work were attempted or done by draftsmen in the owner's office; but if the consulting engineer is honest and proficient, he should give value many times for the money received, and the result should be better service and lower ultimate cost. The rule previously stated will nearly always apply—that the greatest degree of efficiency and economy on construction work is secured only when it is under the direction of an experienced, proficient and conscientious person. Such men, by their superior knowledge are able to save money for their clients, and to show results corresponding to the degree of confidence which can be placed upon them.

The qualities needed in an industrial engineer are knowledge and experience, together with enough force of character to claim and hold the confidence of those with whom he is doing business. He must be able to design, illustrate and superintend his work, or to direct others in such duties. While he must have a general knowledge of his whole business, he should have among his assistants, men specially trained in different kinds of work, as, for instance, one or more draftsmen on mechanical equipment, another on architectural drawings and perspectives.

The word "engineer" is used instead of "architect," in the above discussion, for industrial problems pertaining chiefly to construction and efficiency are better understood by engineers than architects. It is true that many persons calling themselves "architects" are among the most skillful workers on industrial plants, but these persons might better be called engineers rather than architects, since architecture is usually accepted as relating more particularly to the esthetics of design and construction. The results have, however, been excellent, for factory buildings are now made which are not only serviceable but also ornamental.

The works management should delegate some one person to represent them in all matters pertaining to the new buildings, so there may be no misunderstanding of orders. This person should clearly explain to the engineer all requirements of the owners, and should thoroughly inform him on all matters that are not clear to him.

Cost of Engineering Service.—In the following paragraphs, it is assumed as axiomatic that the best service with greatest

efficiency and least cost is obtained from those who are competent, experienced and conscientious, even though these qualities are often hard to find in one person. Owners are usually unwilling to entrust important matters involving the expenditure of large sums of money, to novices or beginners. It may, therefore, be assumed that in employing an engineer, the owner will prefer a man whose experience and ability would enable him to earn an income of at least \$4500 to \$6000 per year, or \$15 to \$20 per day. He should in any case be paid enough to place him beyond the need of resorting to questionable transactions in order to make a living. As the general expense of an engineering office will amount to about as much as the bill of wages, the actual cost without profit for the services of such an engineer alone would be \$30 to \$40 per day. Minimum charges of \$40 to \$50 per day are therefore quite reasonable.

The following are the charges made a few years ago by a firm of architects and engineers where the writer was chief engineer, the percentage being on the total cost of work.

SCHEDULE OF CHARGES

Preliminary studies only	1	per cent.
Preliminary studies, general drawings and specifications	2½	per cent.
Preliminary studies, general drawings, specifications and details	3½	per cent.
Full professional services including supervision	5	per cent.

Commission computed on entire cost of work.

Traveling expenses to be paid by clients.

Two and one-half per cent. is due when drawings and specifications are ready for contractors, and 1½ per cent. when contract is let.

Under present prices (1912) a commission of 5 per cent. should apply only to very large and plain buildings without much detail. For smaller buildings or more complicated ones, the commission should be not less than 6 per cent. In preliminary work, as it is often difficult to determine the value upon which to base the engineer's commission, it may be more definite and satisfactory to undertake such work on a fixed charge per day for the engineer, with extra compensation for each assistant, traveling or other extra expenses to be paid by the owners.

The customary charges, and agreements between owners and engineers, can best be shown by giving the regulations of several Engineering Societies.

Professional Services of Consulting and Construction Engineers

(Engineers Club of St. Louis.)

Schedule of Charges.—The following schedule of charges is intended as a guide to engineers and their clients. It is adopted as representing fair and proper compensation for engineering services under the conditions stated, and is believed to conform to the established practice of leading American engineers. The propriety of a per diem or percentage charge is recognized, varying in amount according to the magnitude or importance of the work involved, or the experience and reputation of the engineer. The right is reserved to depart from the schedule at any time if such action seems wise and proper.

1. For preliminary study and report upon a project, or examination of a project prepared by another engineer and a report on same:

a. Charges, $50 to $100 per day for the first two to ten days, and $25 to $50 per day thereafter, plus all expenses, including salaries paid assistants with an allowance of 25 per cent. of such salaries for general office expenses.

b. In lieu of the above, at the option of the engineer, a percentage charge varying from 1 to 2½ per cent.

2. For preliminary study, report and final detail drawings and specifications:

Charges same as under paragraph (1 *a*) or at the option of the engineer, charges of 3½ per cent.

3. For preliminary study and report, preparing detail drawings and specifications, awarding contracts and acting in a general supervisory capacity during construction, including office consultation but not including continuous supervision, inspection, testing or management-work costing $10,000 or more, 5 per cent.

For work costing less than $10,000, it is proper to charge a fee in excess of 5 per cent.

4. For full professional services and management, including preliminary studies, detailed drawings and specifications, awarding contracts, active and continuous supervisions, testing and inspection—work costing $10,000 or more, 10 per cent.

For work costing less than $10,000, it is proper to charge a fee in excess of 10 per cent.

5. For investigations and reports involving questions in dispute and intended for use in connection with expert testimony:

Charges.—A minimum fee or retainer of $100 to $500 or such larger amounts as may be commensurate with the financial importance of the case or the labor involved, with per diem and expense charges as per paragraph (1 *a*).

6. Where a per diem charge is made, six hours of actual work shall be considered one day. While absent from the home city, however, or while attending court, each day of twenty-four hours or part of a day shall be considered one day, irrespective of the actual hours of time devoted to the case.

7. When charges are based on a percentage of the cost, the commissions as above are to be computed on the entire cost of the completed work or on the estimated cost pending execution or completion. Payments shall be made to the engineer from time to time in proportion to the amount of work he has done.

8. Traveling expenses as well as any expenses involved in the collection of the data necessary for the proper designing or planning of the structure or project such as borings, soundings or other tests, and excepting only ordinary measurements and surveys, are to be paid by the client in addition to the commissions herein provided.

9. When alterations or additions are made to contracts, drawings or specifications, or when services are required in connection with legal proceedings, failure of contractors, franchises or right of way, a charge based upon the time and trouble involved shall be made for same in addition to the commission herein provided for.

10. Drawings and specifications are to be considered the property of the engineer, but the client is entitled to receive one complete record copy of same upon payment of actual cost of making copies, if no duplicate set is on hand.

Professional Code and Schedule of Fees for Consulting Engineers, Adopted June 29, 1911

(The American Institute of Consulting Engineers, New York)

Code of Professional Ethics.—It shall be considered unprofessional and inconsistent with honorable and dignified bearing for any member of the American Institute of Consulting Engineers:

1. To act for his clients in professional matters otherwise than in a strictly fiduciary manner or to accept any other remuneration than his direct charges for services rendered his clients except as provided in Clause 4.

2. To accept any trade commissions, discounts, allowances, or any indirect profit or consideration in connection with any work which he is engaged to design or to superintend, or in connection with any professional business which may be entrusted to him.

3. To neglect informing his clients of any business connections, interests or circumstances which may be deemed as influencing his judgment or the quality of his services to his clients.

4. To receive directly or indirectly any royalty, gratuity, or commission on any patented or protected article or process used in work upon which he is retained by his clients, unless and until receipt of such royalty, gratuity or commission has been authorized in writing by his clients.

5. To offer commissions or otherwise improperly solicit professional work either directly or by an agent.

6. To attempt to injure falsely or maliciously, directly or indirectly, the professional reputation, prospects or business of a fellow engineer.

7. To accept employment by a client while the claim for compensation or damages, or both, of a fellow engineer previously employed by the same client and whose employment has been terminated, remains unsatisfied, or until such claim has been referred to arbitration, or issue has been joined at law or unless the engineer previously employed has neglected to press his claim legally.

8. To attempt to supplant a fellow engineer after definite steps have been taken toward his employment.

9. To compete with a fellow engineer for employment on the basis of professional charges by reducing his usual charges and attempting to underbid after being informed of the charges named by his competitor.

10. To accept any engagement to review the work of a fellow engineer for the same client, except with the knowledge and consent of such engineer, or unless the connection of such engineer with the work has been terminated.

Schedule of Fees.—As a general guide in determining the fees for professional services, The American Institute of Consulting Engineers recognizes the propriety of charging a per diem rate, a fixed sum, or a percentage on the cost of work as follows:

Per Diem Rate.—1. Charges for consultations, reports and opinions should vary according to the character, magnitude or

importance of the work or subject involved, and according to the experience and reputation of the individual engineer from $100 per day to a higher figure, and in addition where expert testimony is required, or where otherwise conditions warrant so doing, a retainer varying from $250 to $1000 and upward. An additional charge should be made for all actual expenses such as traveling and general office expense and field assistants and materials, with a suitable allowance for indeterminate items. In some cases six hours of actual work should be considered one day, except that while absent from the home city each day of twenty-four hours or part thereof, shall be considered one day, irrespective of the actual hours of time devoted to the case.

Fixed Sum.—2. A fixed total sum for above-mentioned services may be agreed on in lieu of per diem charges. A fixed sum may also be charged for a portion or all of the items of preliminary survey, studies, examinations, reports, detail plans, specifications, and supervision, including all the expenses above recited under per diem rate.

Percentage on the Cost of Work.—3. For preliminary surveys studies and reports on original projects, or for examination and report on projects prepared by another engineer, including in both cases all expenses of every nature except those that may be specifically omitted by agreement—from 1½ per cent. to 3 per cent. on the estimated cost of the work.

4. For the preliminary stage (No. 3) and in addition thereto detail plans and specifications for construction, including all expenses of every nature except those that may be specifically omitted by agreement—from 2½ per cent. to 5 per cent. on the estimated cost of the work.

5. For the preliminary and middle stages (No. 3) and (No. 4) and in addition thereto general supervision during construction, including all expenses of every nature except those that may be specifically omitted by agreement—5 per cent., but more for work costing comparatively small amounts, and from 4 per cent. to 5 per cent. where the amount involved is considerable.

6. For full professional services (3), (4) and (5) and management, including the awarding of contracts, and including all expenses of every nature except those that may be specifically omitted by agreement—10 per cent., but more for work costing comparatively small amounts, and 6 per cent. to 10 per cent. where the amount involved is considerable.

7. When desired, the percentage basis may be adopted for one or more stages, supplemented by a daily or monthly charge or fixed sum for the remaining stage or stages.

General Provisions.—8. The period of time should be designated during which the agreed percentages and daily or monthly charges or fixed sum shall apply and beyond which period an additional charge shall be made.

9. The percentages are to be computed on the entire cost of the complete work or upon the estimated cost pending execution or completion.

10. Payments shall be made to the engineer from time to time in proportion to the amount of work done.

11. When alterations or additions are made to contracts, drawings or specifications, or when services are required in connection with negotiations, legal proceedings, failure of contractors, franchises or right of way, a charge based upon the time and trouble involved shall be made in addition to the percentage fee agreed upon.

Contract between Engineer and Owner.—The following blank form of contract is taken from Kidder's Architects' Pocket Book with slight modifications, and will be found convenient.

Contract between.............................Engineer, and..Owner.

For a compensation of ...., the engineer proposes to furnish preliminary sketches, contract, working drawings and specifications, detail drawings and general superintendence of building operations, and also to audit all accounts, for a .... to be erected for ...., at ....

Terms of payment to be as follows: Two-tenths when the preliminary sketches are completed; three-tenths when the drawings and specifications are ready for letting contracts; thereafter at the rate of .... per cent. upon each certificate due to the contractor.

If work upon the building is postponed or abandoned, the compensation for the work done by the engineer is to bear such relation to the compensation for the entire work as determined by the published schedule of fees previously given.

In all transactions between the owner and contractor, the engineer is to act as the owner's agent, and his duties and liabilities in this connection are to be those of agent only.

A representative of the engineer will make visits to the building for the purpose of general superintendence, of such frequency and duration as, in the engineer's judgment, will suffice or may be necessary to fully instruct contractors, pass upon the merits of material and workmanship, and maintain an effective working organization of the several contractors engaged upon the structure.

The engineers will demand of the contractors proper correction and remedy of all defects discovered in their work, and will assist the owner in enforcing the terms of the contracts; but the engineer's superintendence shall not include liability or responsibility for any breach of contract by the contractors.

The amount of the engineer's compensation is to be reckoned upon the total cost of the building, including all stationary fixtures.

Drawings and specifications are instruments of service, and as such are to remain the property of the engineer.

Approved and accepted,
Chicago, June 1st, 1912. By

.... Engineer.

.... Owner.

A shorter form of contract, which will in many cases be quite satisfactory is as follows:

Short Form of Contract.—The undersigned hereby agrees to employ .... Engineer, to furnish scale drawings, details, specifications, and to do the superintendence for a building at ...., at the rate of .... per cent. commission for drawings, and .... per cent. commission for superintendence, the commission to be based on the lowest bid or bids received on the work as an entirety. Furthermore, that in event of abandonment after preliminary sketch has been submitted, ... will pay said Engineers the sum of .... Dollars ($......) on demand for said sketches, and if work is abandoned after scale drawings, details and specifications are completed, ... will pay the full .... per cent. of lowest estimate as an entirety.

Signed

.... Owner.

The above contract is hereby accepted by

.... Engineer.

CHAPTER II

MANUFACTURING DISTRICT

Selection of Manufacturing District.—The selection of the most advantageous district is in some respects one of the most important features of shop economics, for if buildings are wrongly placed, they must continue operation under serious handicap, or else meet the alternative of removal. The considerations which are of chief importance in selecting a district are as follows:

1. Place—city or suburb.
2. Cost of land and ground area required.
3. Labor supply and wages.
4. Nearness to raw materials and fuel.
5. Nearness to source of power.
6. Shipping facilities.
7. Climate.
8. Market for manufactured products.

It is rarely possible to find a place having all the desired requirements, and the best that can be done after weighing the pros and cons of several possible districts is to select the one which has the greatest number of advantages.

1. When contemplating a site in any region, a choice must first be made between large cities and smaller ones, or a suburban or country district. The advantage of a large city is that the proposed business is more closely in touch with other business; that additional help can be quickly found when needed; that a city enterprise is more easily financed than a rural one, and that shops so located become more quickly known and are in themselves an effective advertisement.

Some of the disadvantages of a large city for manufacturing are the high cost of land and necessity in most cases of using multi-story buildings; the smaller chance for expansion; the transient habits of city workmen; the difficulty of keeping a permanent force; the lack of personal touch between employer and employee; greater difficulty from trade unions; higher cost

of living; the imposition in many cases of city building laws; and altogether the difficulty in finding ideal conditions. Taxes in a city may amount to $40 or $50 per year for each employee, while in the country or in a suburb they may not exceed $5 per year.

Small cities or suburban districts are usually preferred, as workmen are not only more comfortable and contented in such places but they are able to do more and better work in good light, pure air and congenial surroundings. The most attractive districts for manufacturing are often within a mile of some small city which has a population of not less than about 25,000, excellent examples being the National Cash Register Works (Fig. 2) at Dayton, Ohio, and the Allis-Chalmers Plant near Milwaukee, Wis. In such places unoccupied land is abundant and can

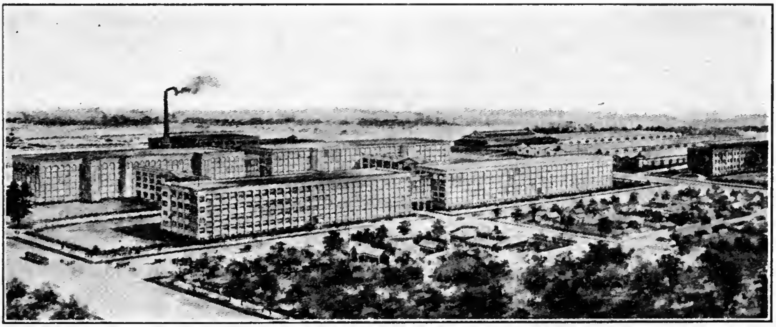


Fig. 2.—National Cash Register Works, Dayton, Ohio.

usually be purchased at prices of $200 to $500 per acre. A district should be chosen near one or more lines of railroad, and adjoining some good water supply such as a lake or river. If a trolley line is not already built along the highway, the presence of a manufactory will very soon bring the desired rail connection to the adjoining town, so that workmen may ride or walk to and from their work as they prefer. There is usually a slight disadvantage from being outside the city limits in that insurance rates are about 25 cents per $100 more than within reach of city hydrants. When placed parallel with and far enough away from a main line of railroad, buildings with signs above them large enough to be easily seen and read by people in passing trains, are in themselves very effective advertising. When thus located on main lines of railway between important towns or

large cities, this kind of display is very impressive, especially when buildings are new and attractive.

A rural or country district, remote from towns or cities, is desirable only in rare instances where other advantages are great and evident, such as the presence of fuel beds, raw material or power. To avoid heavy freight charges, clay industries and brick yards must usually be placed where the clay is found, or to save transmission expense, the presence of natural water power may sometimes be reason enough for building the plant away from a town but near the water power. When too far from town, the company must invest extra money in houses for their workmen, which has been done in many cases, such as at the plants of the Maryland Steel Company, and some of the American Bridge Company's plants. These houses should be comfortable and commodious, and in keeping with other accommodations for employees in modern industries. Congenial surroundings for workmen are not a philanthropic measure on the part of employers, but rather an assistance in securing and retaining a proficient class of operatives.

After choosing between large and small cities, or one of their suburbs, the other matters outlined at the beginning of this chapter may be taken up in order.

2. The three most important considerations in selecting a manufacturing district are the cost of land and presence of labor and raw materials, the first of these frequently being the most important. If too much money is invested in the land, the rent, taxes and interest on the investment may be such a heavy charge against the business as to seriously reduce the possible dividends. In large cities, land is often more valuable than the buildings on it, and the money which might be received by selling the city land would pay for both land and new buildings in a less expensive district. Certain lines of industry require so much ground for their one-story shops, and for yards and tracks, that city land may not only be too expensive, but a block of the required size may not be obtainable. Car shops, structural works, and nearly all kinds of metal working shops come under this heading.

In the business district of New York City, lots sell for $100 to $600 per square foot, and in the central part of Chicago and Boston, from $90 to $100 per square foot. In Chicago, land constitutes 55 per cent. of the whole value, and improvements only 45 per cent., while in Boston the land values are nearly 50

per cent. more than improvements. The land in Cleveland, as a whole, is valued at 40 per cent. more than all the buildings, and similar proportions apply elsewhere.

3. The need of abundant labor is so important that the tendency is to place new works in the vicinity of others making the same kind, or similar goods. Skilled labor for iron works is abundant in such cities as Cleveland and Pittsburg; for cotton mills, in Massachusetts and Rhode Island; for packing houses, in such places as Chicago and Kansas City; and for automobile factories, at Detroit and other cities in Michigan. The prevailing rate of wages also varies according to location, being lower in the Southern States and most parts of Canada than in the Eastern and Middle States, or on the Pacific Coast. As the cost of labor is continuous and is sometimes half the operating expense, a small difference in the rates paid is likely to be quite large in the aggregate. A less cost of labor and building material may also cause an important reduction in the cost of building the plant.

4. When a large amount of raw material and fuel is used, it is desirable to select a district near to one or both of them, where the total cost of all transportation charges will be a minimum. Nearness to materials is, therefore, of most importance in plants with heavy products, and the need of such a location decreases with the volume of freight. For light manufacture, where the cost of products depends chiefly on the labor expended on them, rather than upon their volume or weight, nearness to supplies is of little importance.

5. Nearness to the source of power is a consideration when direct water power and turbines are used. This kind of power, however, is not so much favored as formerly, for it can better be used now for generating electrical currents, which are more easily transmitted. Thirty years ago, water power sites were at a premium, and the growth and business of many cities such as Lawrence and Lowell, Mass. were largely due to the presence of such power.

6. It is an advantage to have at least two competing lines of railway serving the plant if the amount of shipping is large, and water transportage may also be convenient, as, in most cases, freight by water is cheaper than by rail. Large cities with many lines of railroad, have the greatest shipping facilities. especially those on the Great Lakes and on the sea coast. For light manufactures, where labor is the chief item of cost, and

the amounts of shipping is small, it may be permissible in some instances to place the plant away from main lines of railway where other advantages, such as cheap land, may be found.

7. Climate is sometimes an important consideration in selecting a manufacturing district, as places which are known to be subject to cyclones, earthquakes, and violent storms are in this respect undesirable. Extreme temperatures of heat and cold, the depth to which frost penetrates, the amount of snow and rain, all affect operation to some extent. It is well known that a cold and bracing climate is invigorating, and for this reason, northern districts are sometimes preferred; northern races such as the Highlanders, Scandinavians and Canadians are usually more energetic and progressive than the residents of warm countries, such as Spain and Italy.

8. The market for products will also affect the selection of a district. If goods are chiefly for export to Europe and other eastern and southern countries, some places on the Atlantic seaboard would probably be the best; whereas, if products are mostly for export to Japan and China, the Pacific coast would be preferred. Manufacturers of agricultural implements find the Central States adjoining the grain belt to be the most convenient, and many such industries may be found in such cities as Chicago, Kansas City, Omaha, and in some parts of Western Canada.

Selection of Building Lot.—After deciding upon the district or region which is best suited for the proposed industry, some one building lot must be selected from several possible ones. In choosing a district, it will be impossible to find a block with all the desired advantages. Features to be considered are: (1) cost, (2) grade, (3) water supply, (4) drainage, (5) foundations, and (6) approaches. There must also be facilities for heating, ventilating and lighting the building, and for development or application of power, as well as for the handling of materials. The selection of a site may also be affected to some extent by the need of fire protection and the degree of permanence desired.

The first cost is really of less importance than expenses, such as wages and freight, that are continuous. A lot which will save the owner $1000 per year by its better facilities for handling, shipping or storing goods, is worth, at 5 per cent. interest, $20,000 more to him than another lot which cannot make such saving. Therefore, if the owner can buy the better lot at anything less than $20,000 more than the other, he is exercising economy.

The grade of lot should be level or nearly so, the preference usually being for a slope of about one-half of 1 per cent. in the direction that goods pass in the course of manufacture. Some low ground is not objectionable, as it can, perhaps, be used for dumping ashes or other refuse. Hillsides are rarely desirable, unless for gravity transportation, such as at mine shafts or stone quarries where the descending loaded car hauls the empty one up the grade.

A supply of fresh water is needed for boiler feed, sanitation, etc., and soft water is preferable to that containing lime or salt. In cities it can be taken from the street mains at a cost of $2 to $4 per year for each employee, which in a plant with 500 people might amount to $1000 or more per year. In this item alone, a lot with a natural supply would, at 5 per cent., be worth $20,000 to $40,000 more to the owner than another one without it.

The lot should be high enough above some adjoining area or channel that it will be well drained, a bed of gravel and sand being the best for this purpose. This sub-strata is also a good one for foundations, especially in plants where heavy loads must be sustained. Quicksand must always be avoided, as it is too uncertain for foundations of any kind, except in cases of extreme necessity.

The roads or approaches to the plant should be put in good condition. Brick is an excellent paving for driveways and walks, as it is easily drained, and horses find a more secure foothold than on a smooth pavement. Cobble stones, while suitable for draft horses, are too uncomfortable for pedestrians.

After carefully considering the advantages of several sites, and selecting the one most suitable for the purpose, a survey should be made by a local surveyor, who has access to other property maps, lines and grades, and a drawing should be plotted, showing adjoining property lines, buildings, roads, water courses, gas and water pipes, with elevations and grade, and all other data which will be of interest to the engineer and owner.

The choice of lot may sometimes be postponed until after the arrangement of departments and buildings, and the total required property areas are determined. If several lots of ground are under consideration, a good method of procedure is to reject successively the least desirable ones, when finally the best one will remain.

CHAPTER III

ECONOMICS OF FACTORY CONSTRUCTION

Before beginning the detail drawings, the following matters of shop economics must be carefully considered, and about in the order as given:

1. Proposed methods of manufacture.
2. Proposed methods of management.
3. Collection of data relative to other similar plants.
4. Schedule of machines which must be housed.
5. Arrangement of machines.
6. Area and elevation of floors for each department.
7. Receiving and shipping facilities.
8. Provision for extension.
9. Arrangement of departments.
10. Preparatory-design of buildings.
11. Approximate cost estimates.

Each of these subjects will be considered in the following pages, and their relative importance will depend somewhat on the nature of the goods produced.

1. **Proposed Methods of Manufacture.**—One of the first duties of an industrial engineer when undertaking the planning of a manufacturing plant, is to inform himself thoroughly in reference to the methods of manufacture and management to be used in the shops after their completion. The owners will have first estimated the probable amount of goods that can be sold or put on the market per year, and from this estimate, reduced to a money value, an approximation can be made of the prospective profits. Considering these profits as interest on an investment, the expenditure that is permissible can readily be determined. For instance, consider that goods to the value of $500,000 could be marketed annually with a profit of 20 per cent. or $100,000. This amount of profit is 10 per cent. interest or dividend on an investment of $1,000,000. With this limiting value and the estimate of goods which can be marketed annually, with due allowance for growth or expansion, an approximation can be made of the required capacity of the new plant.

All these matters are most familiar to the factory owner, and he must inform the engineer of his requirements. If the buildings are extensions to those already in use, he must explain for what departments the new ones are intended and the special requirements of those departments as well as their probable output. All of these matters may be studied personally by the owner when the plant is small, but in larger works one or more persons are frequently employed, each of whom makes it his special duty to investigate matters pertaining to shop equipment, arrangement, production methods and management, and to this individual, whether executive or owner, the engineer must look for data in reference to the proposed methods of manufacture. Such study is indeed, in many plants, one of the most important duties in connection with the whole enterprise, for it involves much research, and investigation of ways and means used by other shops manufacturing the same or similar goods. In order to secure such information some managers even resort to the questionable method of advertising important positions vacant, for the purpose of securing applications from men employed in similar shops, not that assistance is needed, but that suggestions from these men are more easily obtained when a prospective position is in view. The policy of the officer in charge of manufacturing methods is to secure new ideas from any or all sources, whether from the humblest employee of his own factory or from important officials of competing companies. Some shops use the "suggestion system," offering premiums to any who furnish valuable ideas which will aid in production, or diminish the cost, and for this purpose letter boxes are placed about the works, in which employees may drop written memoranda which may be valuable to the management. Whenever any of these suggestions are put into use, the person contributing it is duly repaid. Profits in manufacturing plants usually depend as much upon the low cost of production, as they do in retail establishments on careful buying, because in both lines of business, selling prices are fixed by those of competitors. Hence, every suggestion or improved method which will reduce the production cost is a proportionate gain.

The matters referred to above are familiar to plant owners and managers, such knowledge being part of their stock in trade, and any data which the engineer needs should be supplied to him. He should make note of the owners' ideas and requirements, and

personally inspect the old shops and similar ones, to better acquaint himself with the needs of the new plant. Matters pertaining exclusively to building construction and methods of lighting, heating, ventilating, etc., are usually better understood by the engineer or architect than by any one else, though even in these matters, the owners will usually have their preferences. For the manufacture of small goods where labor rather than materials is the largest element, buildings of rectangular plan in several stories are usually preferable, with the advantage that a change is more easily made in the arrangement of machinery or departments, but shops for the manufacture of larger goods, such as heavy machinery, must usually be of some special form.

2. **Methods of Management.**—During the last few years, great progress has been made in methods of shop management, and several valuable books have been written on the subject. For this reason, and with the prospect of further improvements in this direction, much foresight is needed when making preparatory plans. As far as possible, it is better to arrange the plant so the administration methods can be changed if necessary. Shop offices, tool rooms and other enclosures should therefore be made with partitions that are removable, and benches, storage cases and other furnishing should be placed and installed so they can be easily changed. The use and position of time clocks may determine the location of doorways for employees and passageways through the shops. Any matters of this kind relating to the subsequent management, may affect the design, and on these subjects the engineer should be informed.

3. **Particulars of Similar Plants.**—Before going further with plans, the engineer should collect and compile data relating to other plants of the same kind, or similar ones. This is most easily obtained from drawings and reports in trade journals, as personal examination of buildings is usually bewildering from their complexity of detail. A personal visit may, however, be beneficial after drawings have been examined, or when these are not obtainable, and on such excursions, a small camera is valuable. Very little data of the kind is now available without original research, and it is for this reason that engineering companies who have collected and preserved such information, are able to prepare plans more quickly than others who are without it. If the new buildings are additions to old ones, the latter should be carefully studied. Floor space, capacity, number of employees,

daily or monthly production, arrangement of contents, etc., should be examined and noted, and the results analyzed, to such ready reference units as floor space and cubic contents of shop per unit of product, or per employee. The cost of buildings, amount of power, etc., should all be noted, and these data and analyses should be preserved for future reference.

New buildings should not necessarily be just like other ones manufacturing similar products, and features should not be copied without knowing fully the reason for their presence, for in the other building there may have been some special need for these features, which does not exist in the new one. Caution must, therefore, be used in these matters. Data of the kind gleaned from journals or drawings, can well be supplemented by practical suggestions from foremen or employees, who are often more familiar than engineers with practical shop needs. If an industrial engineer is not in possession of information of this kind, several months might profitably be spent in investigation and research, and owners are frequently willing to wait, in order to have a more efficient plant. In other cases, when new projects are undertaken, owners prefer to see results at once, even at a somewhat greater initial cost, in order to have their goods on the market and earning dividends. Industrial engineers are therefore wise to provide themselves beforehand with as much data as possible, pertaining to other plants. When facts must be collected for a particular industry, several men may be employed in research, each one taking a special part, and the whole may afterward be assembled and arranged by one person. Uniform methods and units must be used, in order that the analysis may be accurate. For example, building areas should be computed either from their inside dimensions in all cases, or from their outside. While studying other plants, especial note should be made of their efficiency, operating and maintenance expense, cost, type of construction, and provision for extension, so that all features of special value may be incorporated in the new plans.

4. **Schedule of Machinery.**—After collecting data relating to the proposed methods of manufacture and management, and to other similar industries, initial work on the new plant may begin. It is better to start with a small plan showing only the essentials without detail, and to develop it as investigation progresses. By this method the final result should be logical.

The schedule of machines to be used in the new shops will depend upon the proposed capacity or output, and the list should either be made by the owner or manager, or should be examined and approved by him. The machines may all be new, or, if the buildings are extensions of former ones, some old ones may be utilized. Those of standard make are usually the cheapest and best, because improvements have been made on them as found desirable from experience. If the regulations of trade unions should in any case, prevent the use of certain machines, others of equal utility can perhaps be substituted. Machines should as far as possible, be used instead of manual labor, that operating expense may be kept at a minimum. The saving of $100 per year in wages will generally warrant an investment of about $2000 in machinery.

It is seldom economical to manufacture light and heavy goods in the same shops, or articles which differ greatly from each other, because some of the machines may then be idle much of the time. A separate schedule of machines should be made for each department.

5. **Arrangement of Machines.**—In arranging the machinery in each department of a shop, efficiency should be the chief consideration. The course of travel taken by goods in process of manufacture should first be studied and established—a duty which should be performed or directed by the owner or manager, and this course should always be either forward or zig-zag back and forth over the shop floor, but never backward. When the sequence of operations has been established, the machines may then be placed accordingly, passageways being left where needed. The arrangement should be such as to require the least total amount of travel and handling, and provision should be made for additional ones when needed (Fig. 3). The building laws of some cities specify the minimum space which will be allowed, as, for instance, in Cleveland where each day worker must have not less than 25 sq. ft. of floor space, and 300 cu. ft. of air, and each night worker 40 sq. ft. of floor and 480 cu. ft. of air.

When layouts have been made showing the contents of each department arranged to the best advantage, the required areas of these departments should be tabulated, open or uncovered parts being kept separate from those which must be enclosed or housed.

The most convenient method of arranging and locating the machines is to first make small scale drawings of each one showing the outside dimensions of the base or foundation, with the part above the floor in dotted lines. These drawings may either be made to the same scale as the floor plans, or since drawings of such small scale are neither easily made nor very accurate, they can be drawn three or four times larger than the desired size, and zinc etchings of the proper reduction made from the drawings. From these zinc plates as many prints may be made as desired, only one plate being needed for each kind of machine, even though several duplicate ones may be used. When zinc etchings are used, the drawings may be so assembled that the blocks or plates will be of some convenient size such as $5\frac{1}{2}$ by 8 in., or 4 by 6 in., the cost of plates being about five cents per square inch. Small scale drawings, or prints from the zinc plates may then be cut up and arranged over the floor plan in the desired order, and temporarily attached thereto with pins. Several alternate arrangements may thus be made, each with a

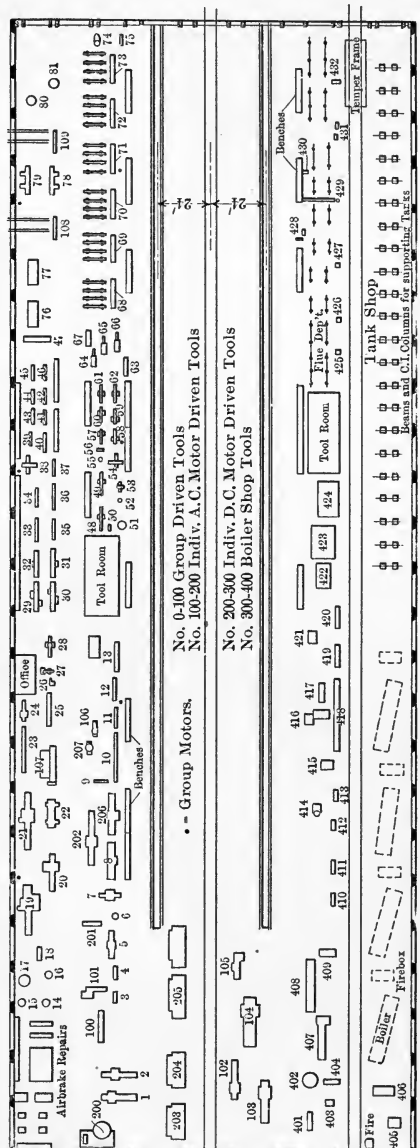


FIG. 3.—Wilmington Forge Shop. Showing location of equipment.

new floor plan and dummies, and when these alternate studies are finished they may be compared and the best features of each selected for the ultimate arrangement.

6. **Area and Elevation of Floor in each Department.**—When the machines have been arranged to produce with the greatest efficiency, the total required area can then be determined. If goods are handled between the machines, there must be space not only for storage but for workmen. The space should not be too large, for compact arrangement saves steps and time. This principle is well understood in house architecture, where small kitchens conveniently arranged are usually preferred to larger ones. The amount of space needed around machines depends to some extent upon the methods of lifting goods, whether by hand or with hoists. Space must sometimes be left for storage and the amount will depend somewhat on conditions. Little is needed when goods in the course of manufacture pass continuously from one machine to another. In other cases

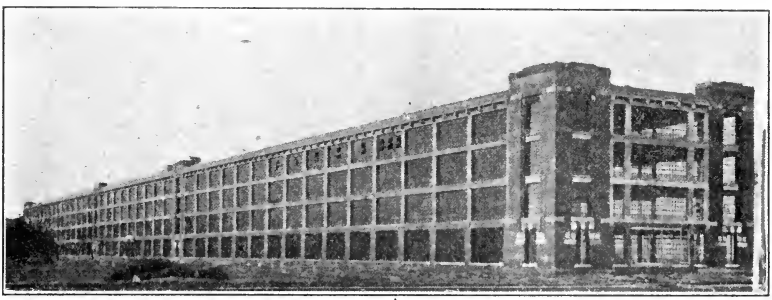


FIG. 4.—Ford Motor Works, Detroit, Mich.

more storage space may be needed, the amount depending on the size of goods and method of piling them. Some space may be saved by storing small parts on racks or shelves.

The tabulated floor areas referred to above, should show the total areas required in each department, with subdivisions giving the amount of space in each case, that must be on the solid ground. Investigation of this table will show the number of stories than can be used, and the probable outline of the buildings. Experience shows, that for cotton mills, four stories are usually the most convenient. Some designers are so enthusiastic over single story shops, as to specify them in nearly all cases,

but like many other comparatively new ideas, the one story shop has frequently been used without sufficient reason.

The width of stories is usually fixed by the need of lighting from the sides. Those of modern design in which a large proportion of the exterior walls is of glass, are well lighted from the side windows in widths up to 75 ft. or more. The Ford Motor Company building (Fig. 4) at Detroit, four stories high, 865 ft. long and 75 ft. wide, is as light inside as any old style building of only half its width.

Adjoining buildings, even though of different widths, should have stories of the same height, if they are ever to be connected by foot bridges. Story heights for buildings of different width are as follows:

Width up to 50 ft..................	Height of story, 12 ft.
Width up to 75 ft..................	Height of story, 13 ft.
Width up to 100 ft..................	Height of story, 14 ft.

7. **Receiving, Storing and Shipping Facilities.**—The importance of these facilities is evident without discussion. Goods

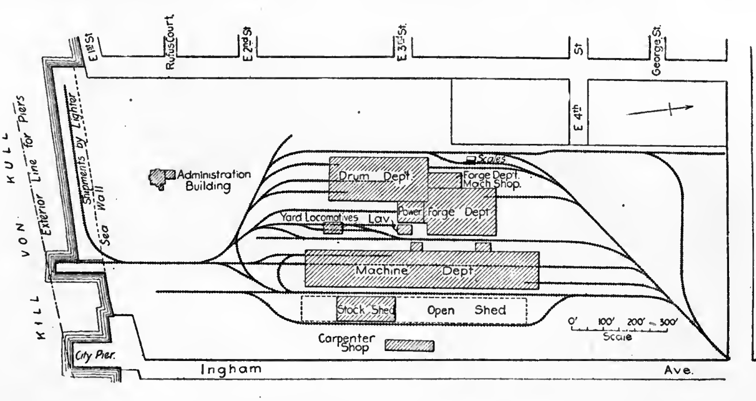


FIG. 5.—Boiler shops of the Babcock & Wilcox Co., Bayonne, N. J.

must be received at that part of the works where manufacture commences, and after passing through the various departments, will be stored or shipped when finished. Switch tracks should branch off from main lines with curves that are not too sharp for standard locomotives, with a radius never less than 235 ft. A comparison of stub end tracks and circuits, yard "ladders", etc., is considered in later pages. Enough sidings and storage space

for raw materials are needed so the railway companies will have no reason for making rental charges on unloaded cars (Figs. 5 and 6). Storage space should be ample for raw materials and finished products, as well as for the temporary accommodation of surplus stock in course of manufacture. The last may be greatly needed when work in one department is delayed by accident or absence of employees, in which case, goods from previous departments can go into temporary storage. If this is not provided

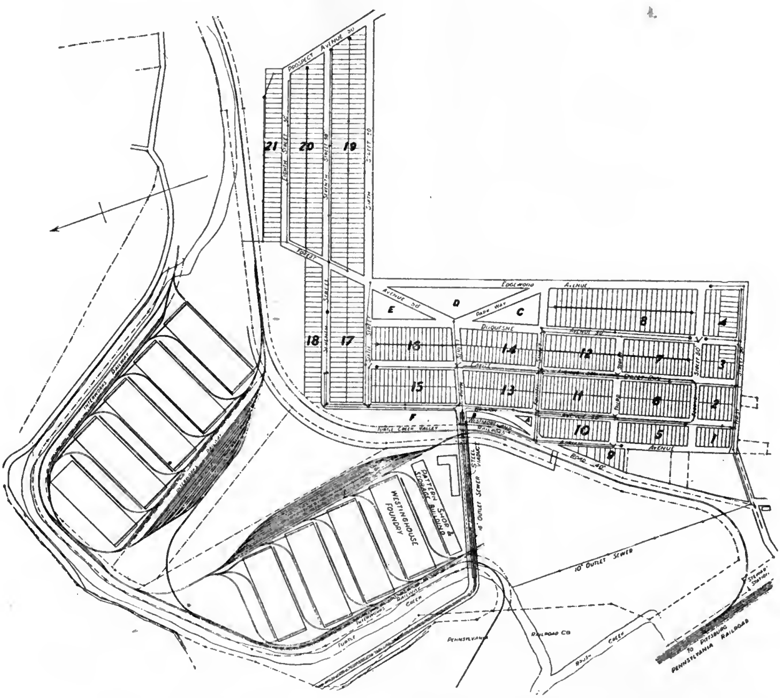


FIG. 6.—Shops and residence tract, Trafford City, Pa.

some departments will be over loaded with goods while others will be delayed. Required storage space which can as well be out of doors should in the tabulation be kept separate from that which must be covered. In small plants, goods in course of manufacture may pass in U-shape through the buildings, so that track may be needed on only one side of the plant, raw material being received at one end of the track platform and finished goods shipped from the other end (Fig. 7).

8. **Provision for Expansion.**—Such rapid progress is now being made in all lines of manufacture, that no plant would be economically planned without provision for expansion. It should in fact be so designed that extension can go on at any time without serious interference with operation—a good way being to lay out a plant much larger than needed, and to build only part of it at first. In many lines of business it is quite safe to anticipate an increase of 100 per cent. in ten years, or 10 per cent. annually. In contrast to systematic provision for extension, may be seen many old plants which have been enlarged by placing new buildings haphazard, wherever space could be found, so that, viewed as a whole, the ultimate condition shows no premeditation. They

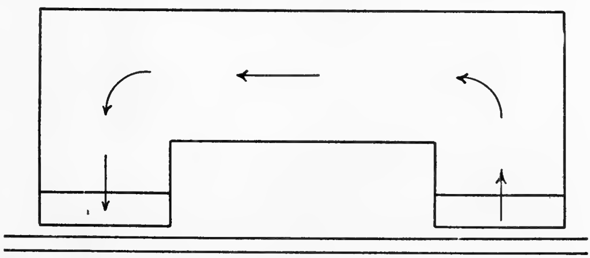


FIG. 7.

are, in fact, nothing more than a cluster of scattered buildings in which business must be conducted under serious disadvantage. To extend a plant by crossing streets in tunnels or over bridges, is not convenient and can usually be avoided if considered in time. Some English shops prefer sideway expansion by the removal of a side wall, and the addition of new buildings with longitudinal roof gutters between them. Endway extension, wings, or upper stories, are other methods of accomplishing the same result. Preliminary provision must also be made for extra land and for the extension of yards, service tracks and trolley lines. Walls which must ultimately be removed should at first be made temporary or of material which can easily be taken down, and reinforced concrete should be avoided unless designed with joints. Plank or sheet metal may be good enough if the buildings are not difficult to heat.

9. **Arrangement of Departments.**—After the machinery has been arranged and the floor area of each department determined, including provision for receiving, storing and shipping, as well as for extension of each, the various departments should

then be assembled into buildings, using regular types as far as possible. Those departments which have noise, smoke, dust, gas, fumes, odors, or fire, must usually be separated from the rest. These will include the rooms for painting, japanning, grinding, polishing and rattling. A foundry and a machine shop cannot well be placed in the same building, for the dust from the first would be a serious injury to machines, and the engine and boiler rooms of power plants should be separated by a brick fire

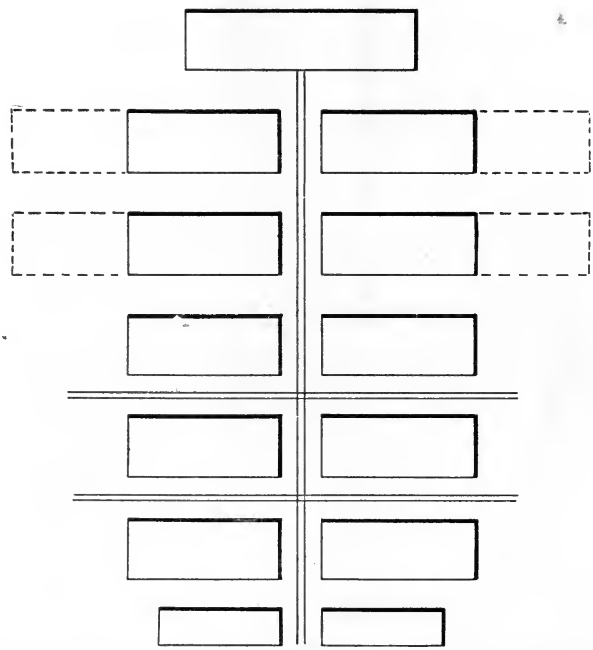


Fig. 8.—Plan of buildings as used on new car shops of the Canadian Northern Railroad Company.

wall. Yet, as previously stated, buildings of regular type are preferable to special ones, for rearrangements, if needed are more easily made. Union and non-union men must sometimes be housed in different buildings. Departments and buildings should be arranged as compactly as possible, with space enough around and between them, and yet with no excess, so there will be no useless travel, an excellent example being the Allis-Chalmers plant in Milwaukee. In special buildings of one story, shop offices will have better light and air when set out from the regular shop

rectangle. Such enclosures as tool rooms, offices, lockers, and toilets may sometimes be on a gallery, though access by stairs is an inconvenience. Some areas may not need enclosing, and may as well be out of doors with a saving of expense. When time will permit, it may be an advantage to make drawings showing several proposed arrangements of departments, and in the final composite, to include the best features of them all.

The grouping of buildings should conform to the course in which goods travel in process of manufacture. In the Allis-Chalmers plant at Milwaukee, for the manufacture of engines and

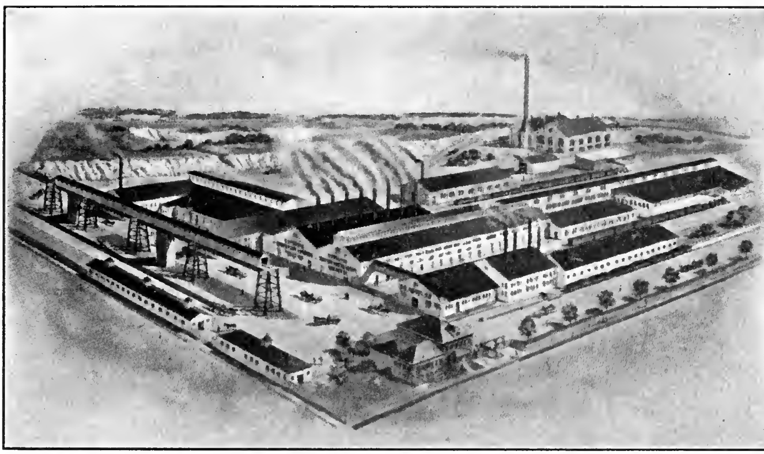


Fig. 9.—Plant of National Portland Cement Co., Durham, Ontario.

machinery, several separate but parallel machine shops are connected at one end to an erecting shop, while at the other end but separated from the machine shops, are a pattern shop and foundry, the axes of which are parallel to the erecting shop. When additional floor space is needed, the erecting and pattern shops and the foundry can be extended endways, and more machine shops placed between them.

Another method of grouping buildings which is very effective, is to arrange them normal to and right and left of a central axis, additions to the buildings when needed, being made at their outer ends (Fig. 8). Extensions do not then disturb the original departments or cause any rearrangement. This method of grouping is used on the new car shops of the Canadian Northern Railway Company at Winnipeg, and is said to be ideal;

the central axis in this case being an elevated craneway covering the tracks which enter the consecutive buildings (Fig. 110).

10. **Preparatory Design of Buildings.**—When departments have been grouped and arranged with reference to each other, sketch designs may be made of the buildings showing the type and materials of construction (Fig. 9). The choice of building type is sometimes affected by their contents and the outside fire risk, though in most cases a fireproof building is preferable to one which is not fireproof, especially when their cost is nearly the same. Fine buildings, when well located, are in themselves an advertisement, and they tend to attract and hold a proficient grade of workmen. The buildings should facilitate production by their good light, pure air, and convenient arrangement, and by

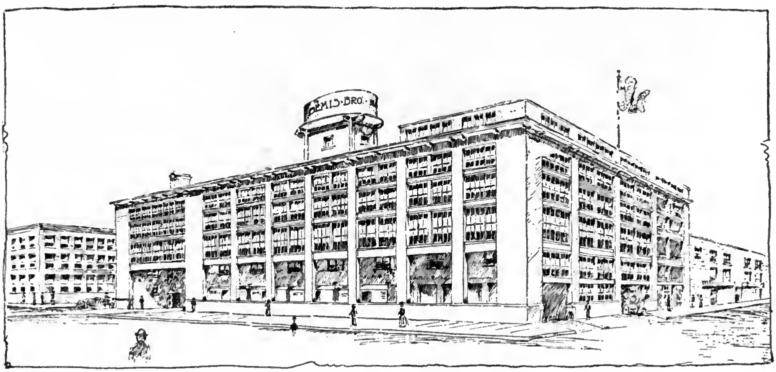


Fig. 10.—Plant of the Gulf Bag Co., New Orleans, La.

their equipment for lifting and transporting materials. No part of the framing should ever interfere with or hinder the processes of production.

Some expenditure may be permissible above the absolute minimum, though this will depend on circumstances. It is better to invest less money in the plant than to incur a debt that will make dividends impossible. Moreover, the proposed new industry may be out of date, and the buildings used for other purposes long before permanent ones are worn out. This condition was well illustrated in the manufacture of bicycles, for only a few years ago many plants were busily engaged in making them. As the demand for them has to a great extent ceased, these shops have been put to other uses, and it is quite possible

that some shops especially built for the manufacture of automobiles may likewise be put to other uses when the novelty of these conveyances and the popular desire for them has diminished. The general rule is that investments are permissible when the corresponding saving or return from such investments will pay interest on the money, together with maintenance, cost and depreciation, with something left over for profit. This is affected by the rate of interest, the number of years that the

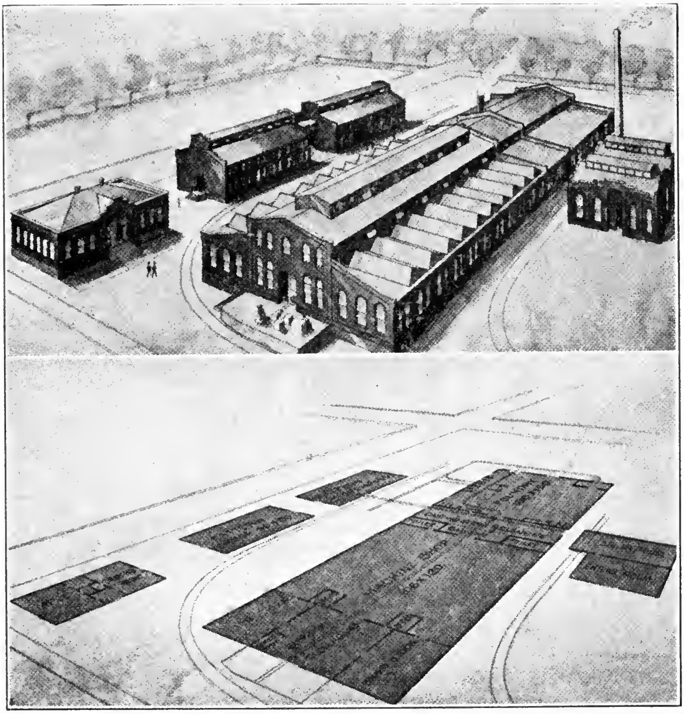


FIG. 11.—Sketch for a porposed light metal working shop.

building will last, and its ultimate scrap value when worn out. In the design of buildings, as well as in the selection of equipment, the final result is usually somewhere between the two extremes of a perfect shop and a practical one.

When a type of building has been chosen which is best suited to the case, outline plans and elevations with one or more

Note.—FIGS. 11 and 12 from Article by D. C. N. Collins, Engr. Magazine, Sept., 1907.

perspectives should be made, that the owner may see clearly how his plant will appear when finished (Figs. 10, 11, 12).

11. Approximate Cost Estimate.—After departments have been arranged and grouped in buildings to the best advantage, an approximate estimate should be made of the whole plant as proposed. Cost units should be large enough and liberal. Buildings may be figured at an approximate cost per square foot of floor area, or per cubic foot of contents; land at the assumed price per acre; machine equipment at a certain unit price per square foot or per employee, which unit will vary for

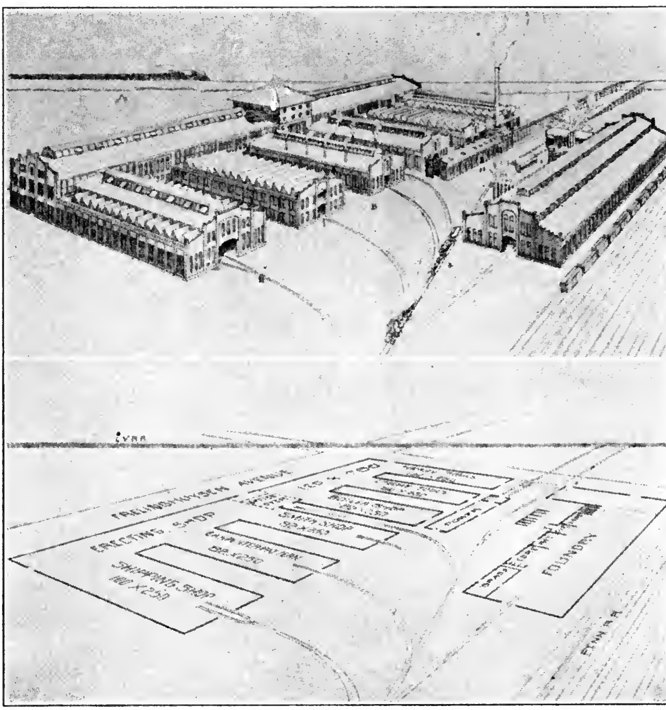


FIG. 12.—Preliminary sketch for an engine and boiler works.

different kinds of shops. The equipment in machine shops for the manufacture of medium or heavy machine tools, will cost about $600 per employee, or about $8 per square foot of shop floor.

Before submitting outline plans and estimates to the owner, the engineer should figure out a number of alternates by which

the cost could be reduced, for an owner often thinks at first that he needs a larger plant than he is finally willing to accept when the cost is considered. Every item of the estimate should be carefully examined to see if it is warranted, and the engineer should be prepared to show where possible changes can be made, and how such will affect the cost.

Plans and estimates should then be presented to the owner, that he may see if the prospective business and profits are enough to justify the investment. If the expense is too large, which is often the case at first, the scope must be reduced. When both owner and engineer are satisfied that the proposed layout and arrangement are satisfactory both as to efficiency and cost, it is then time to proceed with the making of detail plans and specifications, and with actual construction. The preparatory work which is sometimes done by a mechanical or plant engineer in consultation with the owner, is then completed.

CHAPTER IV

PRELIMINARY DESIGN AND REPORT FOR A STRUCTURAL PLANT

In order to more fully illustrate the subject, an example is given of a preliminary design and report for a proposed plant, made by the writer about twelve years ago. A small plant is chosen in preference to some larger ones, as it illustrates the subject quite as well, with less complexity of detail. The plant was an addition to a rolling mill which was then equipped with machine and forge shops, and served by both rail and water shipping. The report is reproduced in full as originally made.

Location.—The most desirable location for the bridge plant is somewhere in the vicinity of the steel mill from which the structural shapes will be received.

As a large part of the output from the bridge shop would be shipped by water, it is desirable to place it near the river. A site just west of the dock would probably be suitable.

It has the disadvantage of being low and wet, and would require considerable grading and filling, probably not less than 2 ft. Some of the material for filling would be taken from the building and machine foundations, but the greater part of it would need to be hauled in on cars.

The triangular piece of ground, bounded by three lines of rail track at the east end of the steel plant would be desirable. This site is drained by the main sewer.

Size of Lot.—To carry out the scheme outlined in this report, the size of lot required is not less than 400 by 1000 ft.

One of the chief requirements of a modern bridge plant is ample yard room.

At one end of the yard, stock should be well spread out on skids, that it may be easily reached with little handling. This end of the yard should be intersected with numerous service tracks.

At the other end of the yard, where the loading is done, there should be ample room for the storage of finished products, and

also for loading them on cars. There should be space for loading several cars at one time, and additional space for shop extension, or the erection of other small buildings as may be required.

Grading of Site.—It is desirable to slope the entire site on a down grade of about 1 per cent. in the direction that the material goes in passing through the works. The cost of this will depend on the site selected.

Arrangement of Yard.—The templet shop and the stock yard are located near one end of the main shop. From these, the stock and templets will be taken to the laying-out department.

It will then pass on to the punches and shears, thence to the assemblers, reamers and riveters, and last to the milling and boring machines. It is then passed out at the other end of the shop, painted, and loaded on cars.

The broad gauge shipping track is shown passing between the main shop on one side and the templet and forge shops on the other.

The main building will have two lines of service tracks passing through its entire length, and the forge shop will have a single line of track.

The stock yard will have several parallel lines of service tracks which are connected by a transfer-way. A service car on any track can then be run on the truck in the transfer-way, and run off again on any desired track.

Cost of the service tracks need not exceed $2500.

Economic Production.—In order to produce economically, and compete successfully for work, it is necessary that the equipment should be the best that can be secured.

In estimating on the plant, only such an equipment has been included as is necessary, but everything is of the best.

Co-operation with Present Machine Shop and Foundry.—These shops are already well equipped, and after the new construction is finished, will doubtless be able to make some parts required by the structural plant.

Such parts as bridge pins, turned bolts, machine screws, finished castings, etc., can be made in the machine shop.

The foundry can produce all the necessary iron castings, and equipment for making steel castings can be added. These will frequently be required in first-class work.

At present there is a corner of the machine shop used for boiler work.

The tools in this corner can be transferred to the structural shop, and all such work done there in the future.

This will leave more room in the machine shop, which appears crowded at present.

Scope of Plant.—This estimate is for a shop equipped to manufacture all kinds of bridge and structural work, including pin-connected and riveted bridges, plate girders, both light and heavy, steel frames for buildings, beams, trusses, columns, tanks, ore boxes, etc., etc. Only three principal buildings are outlined at present, viz.: the templet shop, forge shop and riveting shop.

The templet shop is to be a two-story building. The upper floor is to be finished smooth, and large enough to lay out templets for large riveted sections, such as roof trusses, etc.

The first story will be used at one end for the storage and drying of lumber, and at the other end for a drafting office.

The forge shop is shown close enough to the main shop so that loads of angles or beams that must be heated and bent, may be easily transferred from one shop to the other and back again.

It would not be economical to send such heavy material over to the present blacksmith shop, a distance of nearly one mile, and back again to the structural shop for riveting and punching.

Loop rods, clevises, rivets, and miscellaneous forging will be done here.

There will be an up-setting machine, an annealing furnace, power hammers, etc.

The roof trusses will be arranged with trolleys and hoists for lifting material.

The riveting shop will have traveling carriages, trolleys, and hoists heavy enough to handle the heaviest girders, and other lighter ones for lighter and smaller work.

The buildings will all be well lighted.

The forge shop will have a timber frame.

For the other two buildings, estimates are made for making the walls either of masonry, or corrugated iron on plank.

To start with, it is the intention to have only such buildings and tools as are necessary to turn out work economically.

Other small buildings may be added in the future.

Future Extension of Plant.—The design should be made so that the end can be removed and the buildings made longer.

Other small buildings will be required as business increases. The following may be needed:

Paint shop,
Storage house for erection tools and rigging,
Separate office building,
Plate bending shed, etc.,

but none of these are included in the present estimate.

Method of Constructing Buildings.—The forge shop may be put up first and used temporarily as a structural shop. This is designed with a wood frame that can be built on the ground by carpenters.

Only such tools need be used as are necessary for manufacturing the frames for the other two buildings. These machines may be placed on temporary timber foundations.

Templets for these two buildings may be made in the present pattern shop, and drawings in the attached office.

Then when the permanent buildings are constructed, the tools may be removed from the forge shop to the main riveting shop, and set up on concrete foundations.

Under these conditions, the cost of manufacture will of course be excessive, but it will be quite as satisfactory as waiting for some other shop to manufacture the frame.

FORGE SHOP

Size: 40 ft. by 100 ft. 20 ft. under trusses.

Wood frame. Covering, corrugated iron on plank.
Trusses 8 ft. apart.
Trolleys on tie beams.
10-ft. continuous sash all around under eaves.
8-ft. monitor with swing sash.

ESTIMATE OF COST

Cost of building complete (including foundations)		$3500
Machinery:		
1 up-setting machine	$ 800	
1 rivet and bolt former	1200	
1 annealing furnace	300	
4 forges (from present blacksmith shop)	....	
4 anvils (from present blacksmith shop)	....	
1 steam hammer	800	
1 steam hammer	1500	
6 hoists at $50	300	
100 ft. track	60	
4 service cars	160	5120
Total cost		$8620

TEMPLET SHOP AND OFFICE

Size: 60 ft. by 150 ft. Two stories. Steel frame. Masonry walls.

Cost of building, complete, including floor, foundations, lighting, heating, etc.		$14,300

If the walls are made of plank, covered with corrugated iron, the cost will be $1800 less.

Machinery:		
1 wood planer	$200	
6 drills	300	
1 saw	200	
1 band saw	400	
1 motor	200	
Belts, pulleys, etc	200	
6 sets small tools	200	1,700
Total cost		$16,000

BRIDGE SHOP

Size: 80 ft. by 400 ft. 22 ft. high under trusses. Steel frame. Masonry walls. Roof: corrugated iron on plank.

Cost of building—including floor and foundation		$28,300
Equipment:		
Cranes and hoists	$17,500	
Heating	2,000	
Electric lighting	800	
Machinery foundations	1,200	
Skids and rails	1,300	
Service tracks	800	
20 cars	800	24,400
Total cost		$52,700

MACHINE TOOLS FOR PROPOSED BRIDGE SHOP

1 plate shear for 60 in.×1 in. metal, motor driven	$ 4,500
1 angle shear for 8 in.×8 in. ×1 in.	3,500
1 angle shear for 5 in.×5 in.×3/4 in	2,500
1 bar shear for 12 in.×1 1/4 in.	2,000
1 punch 30 in. throat for 1 1/4 in. holes in 1 in	1,600
1 punch 20 in. throat for 1 1/4 in. holes in 1 in	1,500
2 punches 10 in. throat for angle 6 in.×6 in.×1 in	2,200
1 plate edge planer	4,500
1 boring machine for pin-holes	1,500
1 beam saw for 24 in. beams	1,300
1 beam saw for 15 in. beams	600
1 beam coping and notching machine	1,800
Milling machine, 54 in. head	3,100
Bender and straightener for beams and angles	2,200

1 air compressor	2,500
2 riveters, 25 in. reach (compressed air)	800
1 riveter, 36 in. reach (compressed air)	500
1 riveter, 54 in. reach (compressed air)	500
10 hoists	500
12 drills and reamers	1,000
Piping for drills and reamers	500
Chippers and caulkers	500
4 rivet furnaces	200
2 emery wheels, 2 grind stones	50
1 bar shear	500
1 threading machine for rods	400
1 angle heating furnace	100
4 electric motors	800
Total cost	$41,750

Loading Facilities.—To load heavy work economically, an outdoor traveling crane is necessary.

For the present, however, loading may be done by two derricks capable of lifting about 20 tons each. They may be operated by two electric hoisting engines.

Cost of two derricks at $400	$ 800
Cost of two hoisting engines at $600	1,200
	$2,000

Erecting Tools and Machinery.—The number of erecting tools and amount of material required, depends on the nature of the structure to be erected, and the number of contracts on hand at any one time.

In erecting the frame of the templet and bridge shops, the parts may be hoisted with a gin pole.

The cost of the necessary rigging including rope, pulleys, hoists, guys, timber, gin pole and hoisting engine, need not exceed $1500.

Power.—In the bridge shop, all of the large machines will be driven by direct connected electric motors, and the small ones by compressed air.

A few small ones such as threading machines, grinders, etc., will be belt driven. These may be grouped and the overhead shafting turned by a separate electric motor.

The templet shop machinery may be belt driven, and power furnished by a separate electric motor.

COST OF COMPLETE BRIDGE PLANT

Summary:

Grading	$ 3,000
Service tracks	2,500
Forge shop, building	3,500
Forge shop, tools	5,120
Templet shop and office	14,300
Machinery	1.700
Bridge shop, building and equipment,	52,700
Bridge shop, tools	41,750
Loading derricks and engines	2,000
Erecting	1,500
Total cost	$128,070

MACHINE TOOLS FOR TEMPORARY SHOP—40 FT. BY 100 FT.

1 plate shear, for 36 in. × 1 in	$ 2,500
1 angle shear, for 6 in. × 6 in. × ½ in.	2,500
1 bar shear, for 12 in. × 1 in	2,000
1 punch, 30 in. throat	1,600
1 punch, 10 in. throat	1,100
1 beam saw for 24 in. beams	1,300
Coping and notching machine	1,800
Bender and straightener	2,200
Air compressor	2,500
2 riveters (compressed air)	800
10 hoists (compressed air)	500
12 drills and reamers (compressed air)	1,000
Piping for drills and reamers	500
Chippers and caulkers	500
2 rivet furnaces	100
1 threading machine	400
2 motors	400
Total	$21,700

COST OF TEMPORARY PLANT

One building 40 ft. by 100 ft. and machinery necessary for making building frames.

Grading	$ 500
Service tracks	400
Building	3,500
Tools	21,700
Loading derricks and engines	2,000
Erecting tools	1,500
Total cost	$29,600

Profit on Investment

Count then on an output of 10,000 tons per year, which is a low estimate. From personal knowledge competitors are producing 20,000 tons per year.

Value of 10,000 tons at $70 per ton is........	$700,000
Profit at 10 per cent........................	70,000
Proposed investment.......................	$130,000
Interest on $130,000 at 7 per cent...........	9,100
Depreciation on stock at 3 per cent..........	3,900
	$ 13,000

Net profit: $70,000, less $13,000, equals $57,000

This is 44 per cent. clear yearly profit on the money invested.

CHAPTER V

GENERAL DESIGN

Having completed investigations of the Economics of Factory Construction, and decided all matters relating to the effect of buildings upon output and efficiency, detail designs, drawings, and specifications must be prepared. These will be based upon the outline sketches or perspectives and cost estimates previously made.

Construction bids on proposed new buildings are usually lowest when drawings are very plain, with little or no chance for misunderstanding. The reason for this is evident, as all contractors then have exactly the same data upon which to base their bids, and tenders are likely to be more uniform. On the other hand, if the plans are indefinite, contractors will not feel safe in bidding unless an item is added to cover uncertainties. Clear and accurate working drawings also pay for themselves many times over in the mistakes which are thereby avoided.

While standard house plans in book form are abundant, there seems to be little or nothing of the kind yet available for shops and factories, new ones in nearly all cases being built to order. This need for special planning makes plenty of work for Mill and Industrial Engineers. In addition to the detail plans for construction, drawings must also be made for the interior equipment, including heating, ventilating, lighting, plumbing, electric wiring, power generation and transmission, line shafting, fire protection, handling appliances, yards and tracks, and for all other features of a special nature. The building must serve as a shelter for its occupants and equipment, should give support for shafting and machinery when needed, and form support for crane and other handling appliances. It should also facilitate as far as possible the economic management of labor.

Before starting detail drawings, the structural engineer if he is not already supplied, should have data or suggestions from the owner on matters pertaining to construction, so that the

owner's preferences in these matters may be observed and the plans and specifications suited to conditions. He should also have complete data on the following subjects:

Climate, possibility of earthquakes or cyclones, prevailing storms, extremes of heat and cold, maximum precipitation and snow fall, depth of winter frost, etc.

Survey of lot, showing storm and roof sewers, sanitary sewers, grade and lot lines, water and gas pipes, etc.

Nature and bearing power of soils.

Local laws relating to building construction, smoke, etc.

Regulation of fire insurance companies.

Proposed water supply for shop service, sanitation, fire and sprinkler pipes, condensers, etc.

Machinery layout for each department.

Assumed floor loads—weights of largest pieces, crane loads, etc.

Foundations for buildings, machines, yard cranes, etc., with note of special provision for underground pipes, tunnels, or drains, which may interfere with foundations.

Height of stories, or overhead space for largest machines and materials.

Power and transmission, whether by belt, rope, shafting, electric wires, with provision for steam and air pipes where needed.

Methods of heating.

Ventilating methods.

Lighting of shops, yards, and entrances, particularly where affected by adjoining high buildings.

Plumbing and sanitation and the effect of health regulations thereon. Installation of pipes for air, water and sprinkler systems.

Fire protection system.

Conveying and hoisting appliances for materials.

Arrangement of tracks, switches, scales, etc.

Width of building, position of columns, kind of material, floors, walls, partitions, doors, windows, roof framing, roofing, and other features of construction.

Many of these subjects will be discussed in the following pages, and each must receive the attention that it merits.

Photographs should be freely made about the new site and then numbered, the direction in which each one was taken being indicated by an arrow with its corresponding number on a print of the lot plan. These photographs will be useful for reference

in the engineer's office and are always valuable records which cannot be disproven.

Esthetic Treatment.—Artistic treatment of modern plants is often a part of a definite policy of their owners. It may be carried out for the purpose of advertising, or to attract and hold a good class of employees, welfare features often being introduced for the same reason. Buildings may indeed often be made attractive in appearance (Fig. 13) at little or no increased cost over those which are severely plain. The tendency in recent years is to beautify not only manufacturing plants, but all other utilitarian structures and engineering works such as dams, power plants, bridges, etc. Water towers when enclosed with walls,

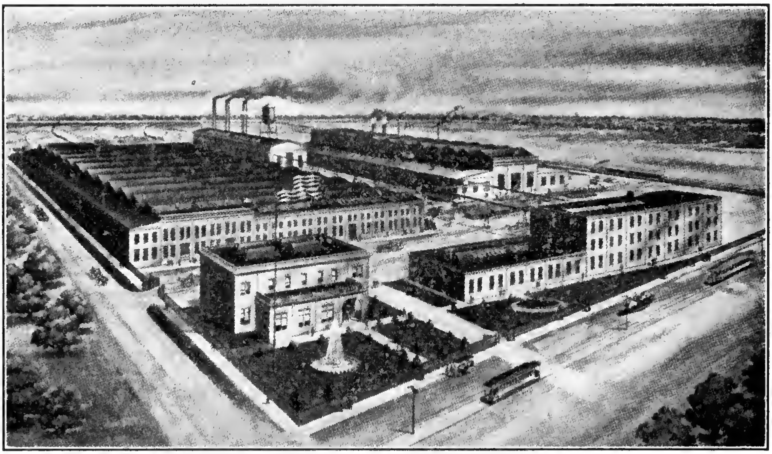


Fig. 13.—Office and works of Pawling & Harnischfeger Co., Milwaukee, Wis.

have a better appearance than those with gaunt and open framing. Colored tiles may be used on roofs, and walls may be relieved with cornices, pilasters, and base of different material or colored paneling (Fig. 14). Interiors of buildings may be painted white or some light hue, and may be relieved with a simple stencil course on the walls near the ceiling, or with occasional decorative panels.

Wind Pressure.—Wind pressure on relatively small areas varies in amount with the height above the ground. This was proven by experiments made in England by Stephenson, on surfaces at heights of 5, 10, 15, 25 and 50 ft. above ground, his observations covering air currents of varying velocities with

pressures of 4 to 43 lb. per square foot. The average results of these experiments are as follows:

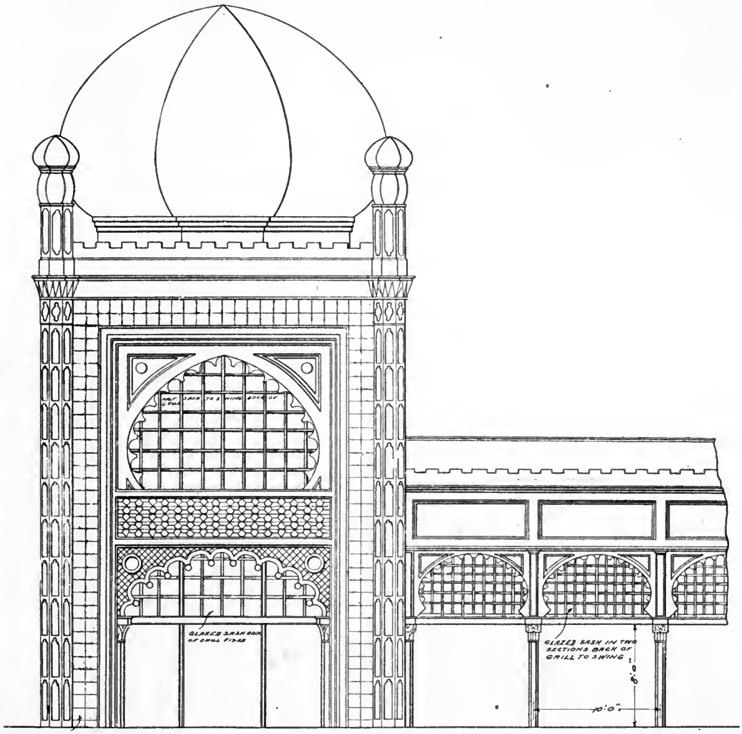


FIG. 14.—Details of market building.

STEPHENSON'S EXPERIMENTS FOR WIND PRESSURE

Height above ground in feet	Wind pressure per square foot in pounds
50	29.1
25	25.9
15	22.8
10	21.2
5	13.8

These results show relative proportions only, on comparatively small exposed areas. As buildings tend, more or less, to shelter each other, especially in districts where they are well surrounded, it is usually sufficient at a height of 80 ft. or more above ground, to provide for a wind pressure of 40 lb. per square foot and for less height to reduce this pressure according to the formula

$$P = 4\sqrt{H} + 5$$

where P is the wind pressure in pounds per square foot, and H the height in feet to the area in question. This gives results conforming closely with Stephenson's experiments, the results being shown on the following diagram.

As a wind pressure of 30 lb. per square foot corresponds with a velocity of 70 to 80 miles per hour, and can occur only during violent storms or hurricanes in exposed places, it is rare, indeed, when a greater pressure need be assumed. The tendency in urban districts, for buildings to shelter each other, is so effective that it is frequently quite safe to entirely disregard wind pressures up to a height of 20 to 30 ft. above ground. There is a tendency on large wall areas toward equalization of pressure at varying heights, owing to the elasticity of the air, the condition being different to that in Stephenson's experiments, which were on small areas.

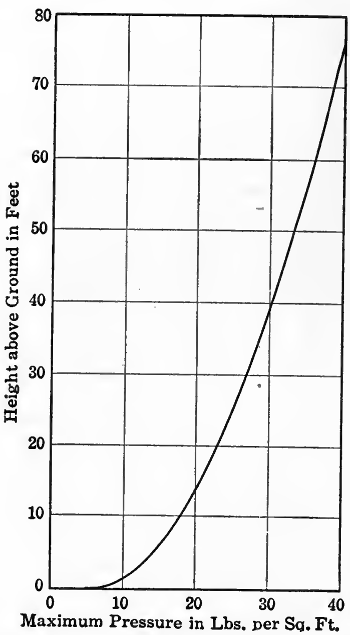


FIG. 15.

Wind pressure on the interior of buildings may be serious, especially where the sides are partly open, or broken with many doors or windows through which air currents may enter. Need of protection against inside upward pressure has long been known, for in some exposed districts in Europe, it has been the custom for the peasants to load their roofs with rocks. The ends of high single-story buildings, such as erection shops with traveling cranes, are often harder to brace than are the sides, for they lack substantial bracing at the lower chord level and at intermediate heights. When the sides are open enough to admit free air currents, wind pressure on the two sides will be nearly equal, and the sum of these sides will be the area under pressure. Wind conditions will evidently vary in different buildings, and each one should be proportioned according to its needs.

Pressure normal to the roof surface for angles up to 75 degrees from the horizontal, corresponding with wind pressures of 40 lb.

per square foot, on a vertical surface may be obtained from the following formula:

$$P = 40 \sin(A + 15 \text{ degrees})$$

where A is the angle which the roof plane makes with the horizontal. The results are conveniently shown by the following diagram, which, if made on tracing cloth, may be laid over roof drawings of any slope and the corresponding normal wind pressure read off directly.

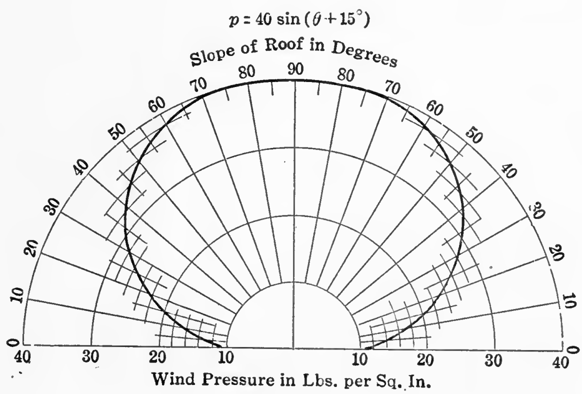


FIG. 16.

Floor Loads.—Live loads on floors vary greatly according to the industry, the largest ones frequently being in metal working shops. The floors of cotton mills can generally be light, for the total weight of machinery, men and materials will seldom exceed 30 lb. per square foot. Stories 8 to 9 ft. in height used for the storage of cotton bales, should be proportioned for an imposed load of 100 to 150 lb. per square foot, while higher ones for general storage and packing, might be subject to 200 lb. Rooms for pattern storage rarely carry more than 150 lb. on the square foot. Buildings for light machinery frequently have provision for loads of 250 to 300 lb.

Unit Stresses.—A factor of four is sufficient for dead and live-load stresses, but for greater combinations such as dead, live, and crane loads all acting together, a factor of safety of three is enough. The temporary buildings for the Columbian Exposition at Chicago in 1893, were proportioned for tensile stresses of 20,000 to 25,000 lb. per square inch of section on steel. Comparatively

high unit stresses are usually permissible on buildings excepting perhaps in columns, for it is well known that such structures rarely fail by the collapse of their principal parts, but rather rack to pieces from the vibration of cranes and heavy machinery.

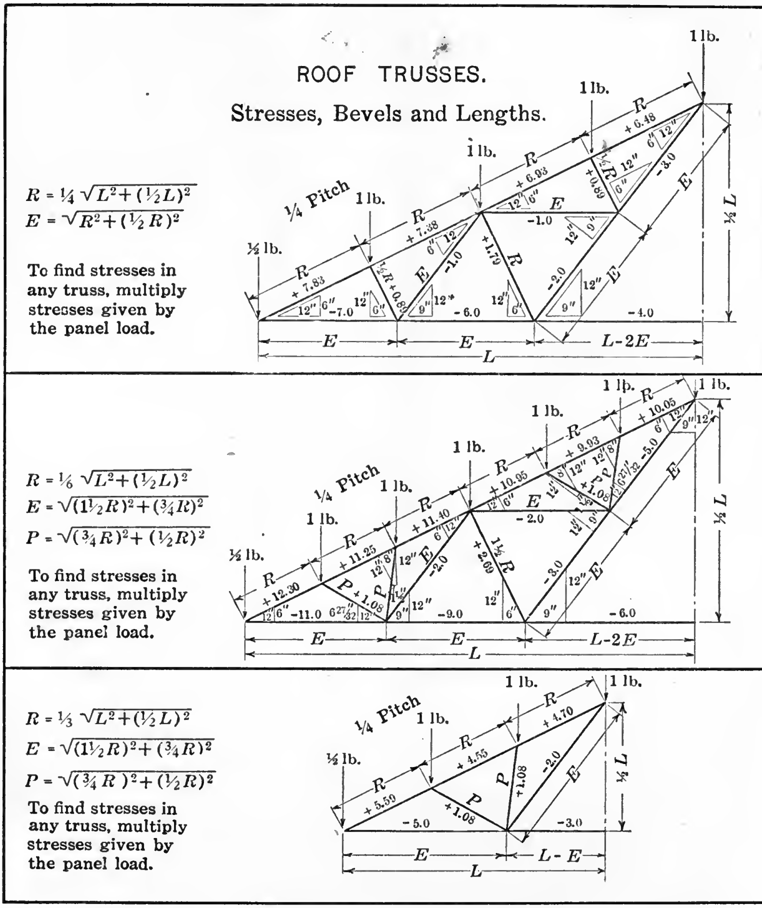


FIG. 17.

Stress Analysis in Building Frames.—The cases to be considered in determining the stress in building frames are as follows:

1. Stress in roof trusses and columns from permanent dead load.

2. Stress from wind acting normal to roof surface, with trusses supported on side walls.

3. Stresses in trusses, columns and knee braces, from wind on side of building and roof, either horizontal or normal to surface, (a) with columns hinged as base, (b) with columns fixed at base.

Partial loading can never cause maximum stress in the parts of a Fink truss, as it may in some other truss forms.

Calculation of truss stresses is greatly simplified by the use of coefficients giving the stress in each piece from panel load of unity, some of these coefficients being given in the following diagrams.

Knee Braces.—Judging from the elaborate analysis given in some books of the stresses in building frames with knee braces,

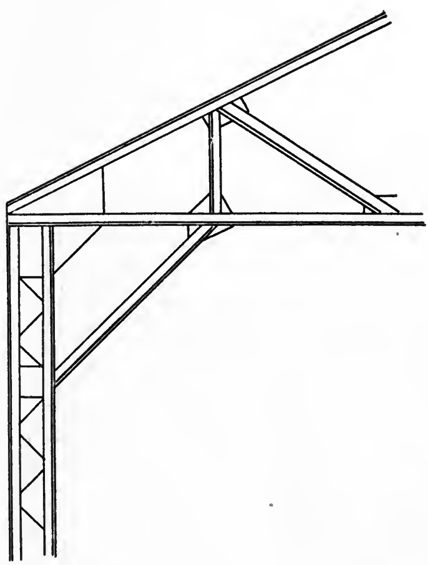


FIG. 18.

a person might almost believe that this comparatively simple feature should receive quite a large part of an engineer's attention when planning such structures. On the contrary, the analysis of such stress is very simple, though it is affected to some extent by local conditions, such as the detail of column base, and amount of anchorage; nature of walls, whether closed or partly open, etc. In many, if not in most cases, the experienced designer can see from inspection that computation of stresses from knee braces is unnecessary, as they are insignificant. But when buildings

4

are high and exposed to strong wind, investigation of knee brace stress may be needed. It is, however, important that knee braces have rigid framing at their extremities (Fig. 18), and they should connect to a truss panel where the members are heavy enough to resist compression. At the other end of the brace, the column must be firm enough to resist bending, web lattice frequently being too light for rigidity. The knee brace problem is quite similar to one of the simplest in bridge analysis, viz., the proportioning of portals. Columns may be considered fixed at the base when they are firmly anchored, or when they have snough load on them to hold them squarely down. A large one-story steel-frame metal working shop which was inspected by the writer after its collapse during erection, but after columns had been anchored, illustrates the case. The columns remained with their bases fixed to the foundations and bent at about one-third of their height, the whole frame falling in one direction.

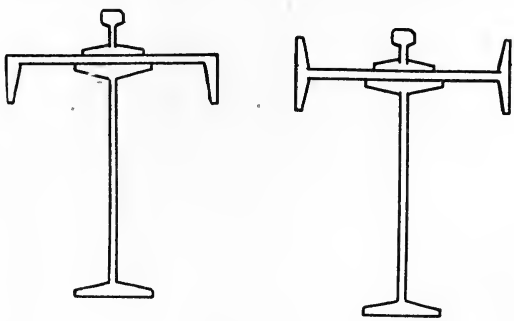


Fig. 19.

Pin ended action is seldom found in building columns. Wind pressures on the bents may usually be considered as transferred to the foundation in equal amounts on the two sides, for if the leaward braces and columns are not stressed at first, deflection of the windward side will bring the other into action.

Columns should be proportioned not only for their direct load, but also for the bending stress and additional load on them from the overturning effect of wind on the building as a whole, causing greater load on the windward ones.

Additional Notes.—In conclusion, the design should be carefully studied out, preferably on small sheets of paper, 8½ by 11 in., and drawings made, giving sizes and general details. The upper flange of crane girders may be stiffened laterally by

placing another beam or channel with its web in a horizontal position above the principal one, the upper one being riveted through the web to the flange of the one beneath it (Fig. 19).

The design should also be checked, and every part reconsidered before construction. Any parts which are found to be unnecessary may then be omitted, or additional ones may be introduced where needed. The dead weight should be refigured to see that it does not exceed that which was assumed. One or more show plans or general drawings should be made, giving all the framing sizes and general dimensions, these plans serving as a guide for the draftsmen when making the details.

Specifications.—Unless a building specification is clear and definite, misunderstanding will surely arise, with correspondingly higher tenders. Successful contractors are not willing to take reckless chances, and they usually add enough to their bids to cover any points which are indefinite. Then, if the contract is secured, and construction should be carried out in a cheaper way, their profit would be increased. For the sake of clearness, the writing of specifications should be deferred until all details of construction are well in mind. A good way is to carefully examine all drawings, whether complete or under way, and to make note of details of every kind, examining each sheet thoroughly in all particulars before taking up another one. Each note should be made on a separate card of uniform size and these may afterward be arranged under different headings, those relating to masonry, carpentry, painting, etc., each being kept by themselves. The cards for each heading may then be classified in proper order. In this way a logical arrangement is easily obtained. Before writing the specifications of any particular subject, such as carpentry work, this branch should be reviewed again on all the drawings to see that everything has been included. Words known as localisms should be avoided, which are used and clearly understood only in certain districts and by local residents, for elsewhere the meaning may not be known. When general requirements are well covered, special features and details should be explained and particularly those which are not easily shown on the plans. Uncertain features may sometimes be covered by "blanket clauses" or comprehensive statements. For the sake of clearness, it is better that all notes on the drawings be repeated in the specifications.

CHAPTER VI

SELECTION OF BUILDING TYPE

The primary object of factory buildings is financial profit, and in this respect they differ from houses or monumental structures, which, in addition to utility, are for comfort and beauty. Manufacturing buildings are merely supplementary to their contents and all the plans should be developed together, the buildings forming a convenient enclosure of the right size and form, for the machinery within. Capital is more easily secured for the erection of buildings of regular form than for irregular ones, because those of the former type can more easily be adapted to other purposes if vacated by the original industry.

Kind of Building Material.—The usual types of factory buildings are:

1. Complete wooden buildings.
2. Slow burning or mill construction framing with brick walls.
3. Steel frame with walls of brick or concrete.
4. Reinforced concrete frame with walls of brick or concrete.

The rule is to select that type in which work can be done with the greatest ease, efficiency and security at the least ultimate cost, when interest, insurance and depreciation are considered. The extent to which building materials will affect the first cost, depends upon their selling price at the place of manufacture, with transportation charges to the site added, and the facility for receiving and hauling them when they arrive. Preference will often be given for that material which is near at hand and therefore more quickly obtained at a lower cost. In those Pacific states where good timber is still plentiful, it is much used in preference to steel, which must usually be brought a long distance—often from Pennsylvania and Ohio. On the other hand, in the vicinity of rolling mills and structural works, steel framing may be more quickly made than timber and at nearly the same cost.

Wood, metal and concrete framing each have their special merits which are mentioned elsewhere. Exposed metal framing is not suitable for buildings where gases or sulphuric acid fumes

are generated, as in locomotive sheds, gas houses, or shops for making storage batteries, for the metal is rapidly corroded by the fumes. Reinforced concrete compares favorably in cost with timber, for buildings of several stories and column spacing of 16 to 20 feet, with floor loads of 250 lbs. per square foot or more. But for one story buildings and especially those with long spans, reinforced concrete for framing cannot compare in cost with steel. Wood sheathing for roofs is cheaper in first cost than slabs of reinforced concrete.

Essentials of Good Framing.—The essential qualities of good framing are:

1. Strength
2. Durability or endurance
3. Utility
4. Simplicity of construction
5. Economy
6. Possibility of quick and easy erection.

The columns, walls and floors must evidently be strong enough to carry their loads, and requirements of the near future should be anticipated, for the strengthening of buildings is difficult and expensive.

Durability or endurance depends much on the absence of vibration, the injurious effect of which is very great. The building must also resist the attacks of weather and the elements, and should be as nearly fireproof as possible.

Utility and efficiency are secured by good lighting, heating and ventilating, together with cleanliness and sanitary conditions.

Simplicity, quick erection and economy are essentials, factors of economy being low cost of construction, maintenance and operation.

Vibration and Oscillation.—Vibration is a local shaking of parts under loads or impact, while oscillation is the swaying of the building as a whole, resulting from the movement of cranes or machinery acting in unison. Both of these cause serious injury to the framing with frequent breaking of skylights and windows. These movements also cause excessive wear on machines and necessitate a greater amount of power to run them. Oscillation often occurs in steel frame buildings of several stories with brick exterior walls, which are used for such purposes as printing and binding, a notable one of seven stories in Chicago having a movement at the top of several inches, even though the five-story

building adjoining it is made of concrete. Recent inspection of this building by the writer showed that such excessive oscillation had a serious effect on the occupants, particularly on occasional visitors unaccustomed to its movement. In a plant valued at $100,000 it has been estimated that the cost of machinery repairs from vibration alone would average one to two dollars per day.

Depreciation.—Yearly depreciation depends upon the ultimate duration of a building, and its scrap value at the conclusion of that period. Slow depreciation usually accompanies high first cost, and rapid depreciation low first cost, though there are exceptions to the rule. Wooden buildings of slow burning construction have a yearly depreciation of 1 to 1½ per cent., while those of reinforced concrete do not exceed ½ of 1 per cent.

Insurance.—The need of fireproof construction is evident, when the annual fire loss is considered, which in the United States alone, exceeds $250,000,000, or $2.50 each year for every person.

Insurance rates vary considerably according to the time and place and to the available water supply and fire protection. Approximate annual insurance charges on buildings of different types for city location, but without sprinkler systems, are given in the following table. The figures are the rates of insurance in cents per $100 of value for both building and contents.

TABLE I.—APPROXIMATE INSURANCE CHARGES

	Concrete bldg.		Wood mill constr., brick sides		Wood mill constr., wood sides	
	Bldg.	Contents	Bldg.	Contents	Bldg.	Contents
General storehouse	20	45	60	100	100	125
Wool warehouse	20	35	40	60	75	100
Office	15	30	35	50	100	125
Cotton factory	40	100	100	200	200	300
Tannery	20	40	75	100	100	100
Shoe factory	25	80	75	100	150	200
Woolen mill	30	80	75	100	150	200
Machine shop	15	25	50	50	100	100
Merchandise building	35	75	50	100	100	150
Paper factory	12	29	21	65	......	....
Average	10–40	30–70	20–75	60–100	75–150	100–200

TABLE II.—INSURANCE CHARGES REPORTED BY ANOTHER COMPANY ARE AS FOLLOWS:

	Concrete bldg.		Wood mill constr., brick sides	Brick and steel construction
	Building	Contents	Building and contents	Building and contents
Pattern storage bldg.	25–50	45–65	85	70
Foundry...........	30–65	65–100	135	115
Machine shop.......	25–50	50–75	100	85

Buildings for Merrit & Co. of Philadelphia had, in 1907, insurance rates per $100 of value for building and contents of

182 cents per $100, for reinforced concrete buildings,

357 cents per $100, for mill construction buildings.

All of the above charges are for buildings without automatic sprinkler systems. When these are installed, the charges are reduced by 50 to 75 per cent. Reports published in 1908 show that the rate of insurance on buildings of mill construction, reinforced concrete, or steel frames not fireproofed, when provided with automatic sprinkler systems, is 20 to 35 cents per $100 per year.

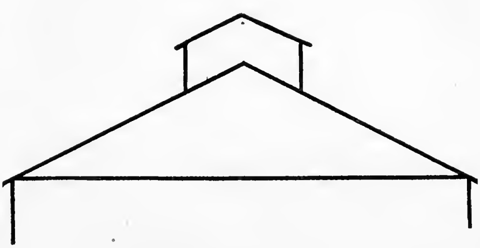
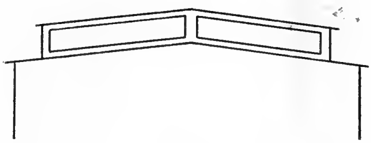


FIG. 20.

Roof Outline.—The exterior roof outline should be such as to shed water, and if necessary, to admit light and air, but it should also be of pleasing appearance. These results are obtained in many ways, some of which are, by double pitch roofs with center monitor (Fig. 20), transverse monitors on flatter pitches (Fig. 21), and single slopes with light admitted from the north side only (Fig. 22). A double pitch roof with a center monitor is an

excellent outline as far as water shedding, ventilation, and appearance is concerned, but it fails in admitting sufficient light. Windows on narrow monitors throw but little light to the floor, and glass skylights must usually be placed on the roof. Skylights are often undesirable in single story metal working shops,



Fig' 21.

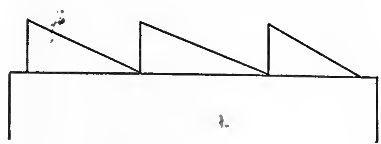


Fig. 22.

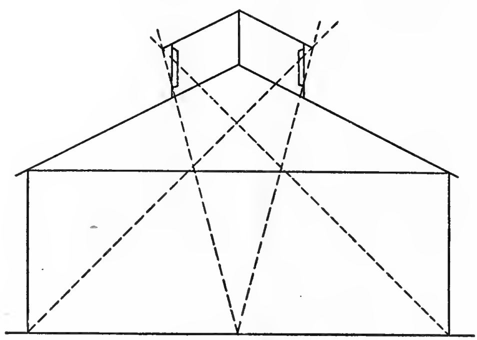


Fig. 23.

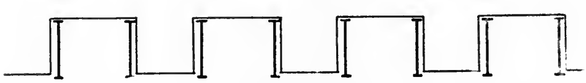


Fig. 24.

Fig. 25.

as they are frequently broken from the action of cranes. The insufficient light from windows on longitudinal monitors is due chiefly to the narrow monitor widths (Fig. 23), which rarely exceed 5 to 10 ft., and for this reason some recent shops have roofs with moderately flat pitch, and transverse monitors

covering the whole width of alternate panels, their sides being covered with movable sash. When these cross monitors inclose pairs of adjoining trusses (Fig. 24), there is economy of interior heating space as the roof outline lies just above the lower and upper truss chords on which the purlins are supported. A good example of this type, is a pattern shop recently erected for the Maryland Steel Company. Instead of covering alternate roof bays, the transverse monitors may be placed at less frequent intervals, and may extend either part way or entirely across the roof. Transverse monitors over every third roof panel, the monitor sides being covered with glass, give good lighting effect. With panel lengths of 20 ft. and cross monitors over every third panel the cost of the two types will be about the same when the

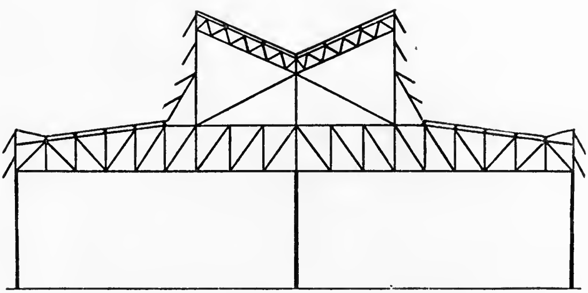


Fig. 26.—Truss outline for effective roof lighting.

length of the cross monitor is 60 ft. or equal to three panels. Longitudinal monitors for lighting should have a width of about one quarter of the span, but when for ventilation only a less width is preferable.

Another plan is to use flat pitch roofs over the central part of the building, with end posts of the trusses near the walls, inclined at angles of about 45 degrees, these side sloping areas being covered with glass (Fig. 25). This position and inclination of glass is excellent for admitting light, but the sloping sash are liable to leak.

As warm air, gas and smoke naturally rise to the highest level, they can be withdrawn only when ventilators are at the summit, and roofs with double pitch descending from the center to the side must therefore have the monitor at the ridge. But as previously stated, this form admits insufficient light through the monitor sides. The outline may, therefore, be reversed, and a

longitudinal gutter placed over the center of the building with a double-pitch roof ascending to the sides (Fig. 26), giving greater window height for light and ventilation. Sash can stand vertical, and objectionable sloping skylights can be avoided. Ventilation is effective without any fire risk when these sash are made of rolled steel and operated in clusters (Fig. 27). This type of

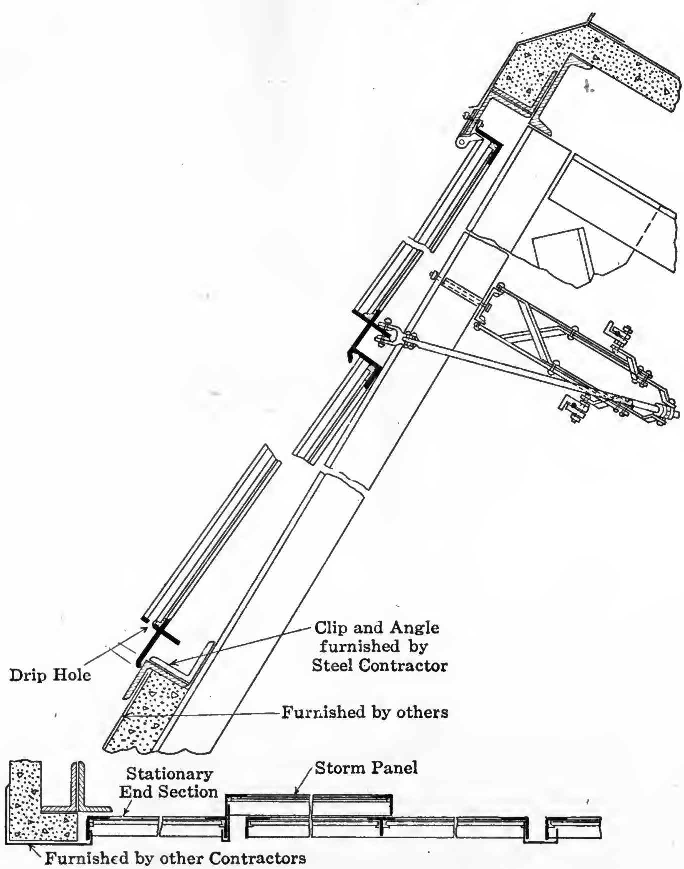


Fig. 27.—Detail of sash for northern light roofs.

roof fulfills all useful purposes but is lacking in esthetic outline.

North light roofs, like many other comparatively new things, have been used to excess, and often with insufficient reason. Their chief advantage is that sunlight is not admitted and shadows are therefore avoided. They have the objection of

increased cost and poorer ventilation. Some recent metal working shops with three longitudinal bays—the central one for

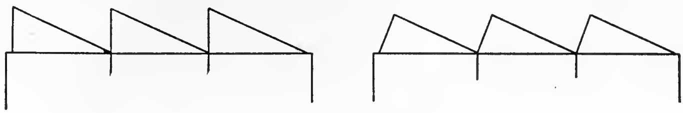


Fig. 28.

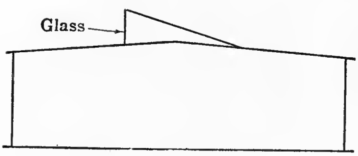


Fig. 29.

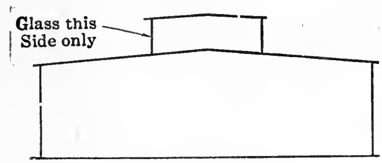


Fig. 30.

erection being higher than the sides, have transverse saw-tooth roofs over all of the bays, while other shops use saw-tooth over

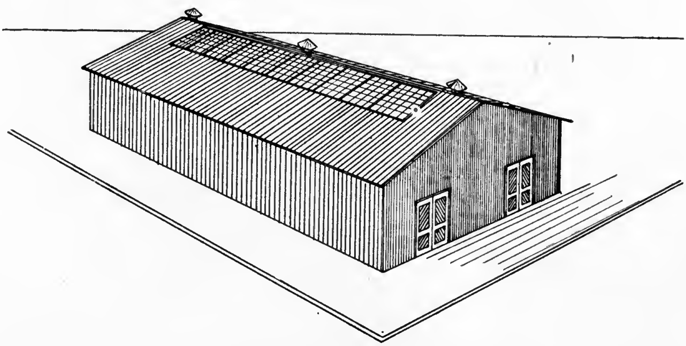


Fig. 31.—Shed with single gable.

the side bays only, with a double-pitch roof in the middle. There is little or no difference in the cost between vertical or

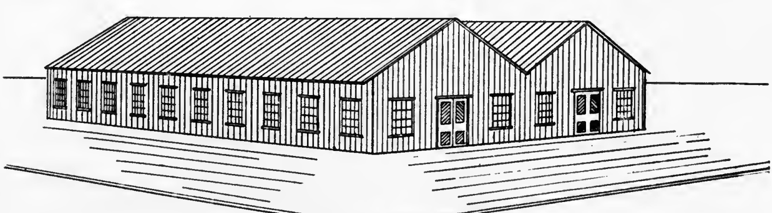


Fig. 32.—Building with double gable.

inclined surfaces for the north windows, for while vertical faces give a greater area to be covered, the cost of framing and opening

the windows is less. The greater cost of vertical sides is, therefore, offset by the less cost of windows (Fig. 28).

North roof light may be admitted to buildings with widths of 60 ft. or less, by placing a single longitudinal monitor over the whole length of the building, with glass on the north side only. This monitor may take the form of a saw-tooth (Fig. 29), or may

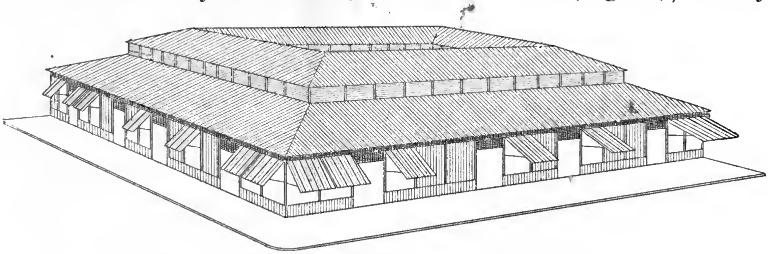


FIG. 33.—Market building around an open square.

be symmetrical with vertical faces on both sides, and the south face covered with sheathing (Fig. 30). An example of this kind with saw-tooth monitor may be seen in the new two-story concrete shop at Cornell University.

Buildings may have either one ridge (Fig. 31), or two (Fig. 32), or may be built around an open square (Fig. 33), a form which is especially suitable for market buildings where an abundance of fresh air is needed.

CHAPTER VII

WOOD AND METAL FRAMING

Timber as a structural material, has lately received wholesale condemnation by those who are commercially interested in reinforced concrete, but the real cause for a decreasing use of

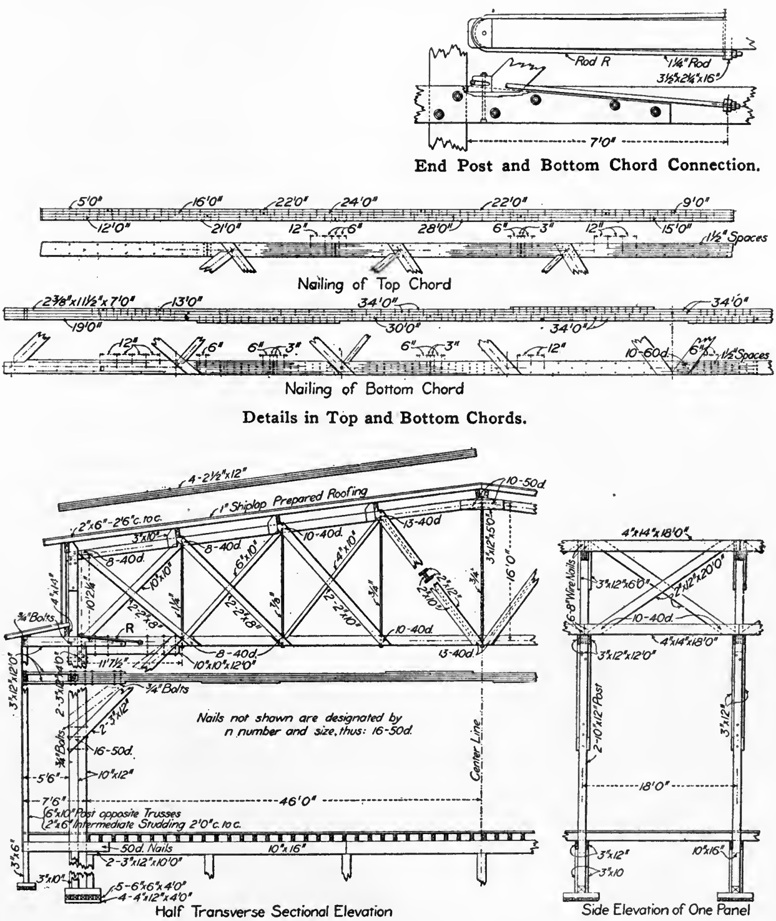


FIG. 34.—Timber framing for auditorium at Seattle.

timber is not its lack of merit, but rather the difficulty of securing it in working lengths and at a reasonable cost. Notwithstanding the increased use of steel and reinforced concrete, the continued importance of timber in construction is shown by a recent report of the United States Geological Survey, covering forty-nine American cities. From this report it appears that tim-

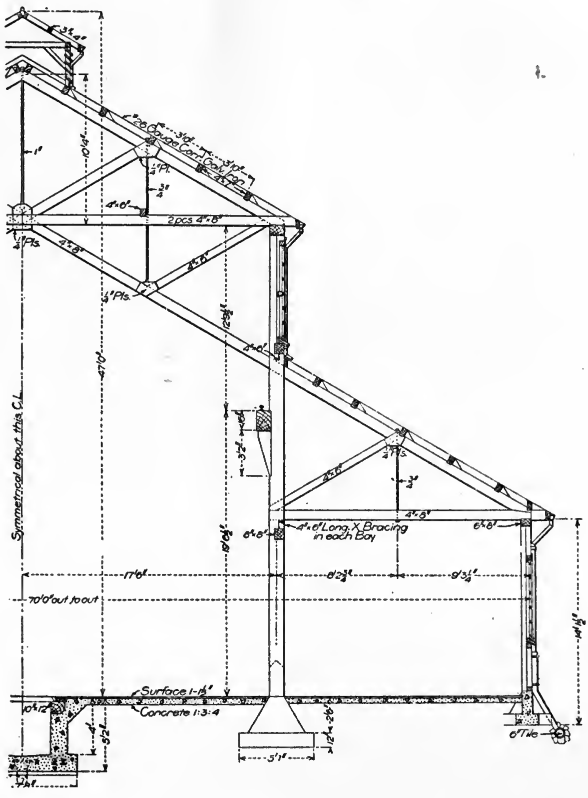


FIG. 35.

ber still constitutes 61 per cent. of all structural material with only 39 per cent. of other materials. In the New England States more mills are framed of wood than of all other materials combined.

Timber has a low first cost, is easily framed, and is often preferred especially in the South and West where it is still plentiful. The objection to timber is its fire risk and corresponding insurance charges. Its general use on the Pacific coast is shown by

such buildings as the large skating rink at San Francisco with trusses 170 ft. long, the auditorium at Venice, California, and a large one at Seattle with a span of 96 ft. (Fig. 34). The rink at San Francisco has bents 20 ft. apart, with a roof pitch of 1 in $3\frac{1}{2}$, and bottom chords in the segment of a circle. Trusses are of Oregon pine planks, and the total roof weight, including trusses, purlins and corrugated iron is 10 lb. per square foot. Figs. 35 and 36 show other details of timber framing.

Even in the East and Middle States, timber is still often favored as evidenced by the erection in 1907, of a roof over the Elysium

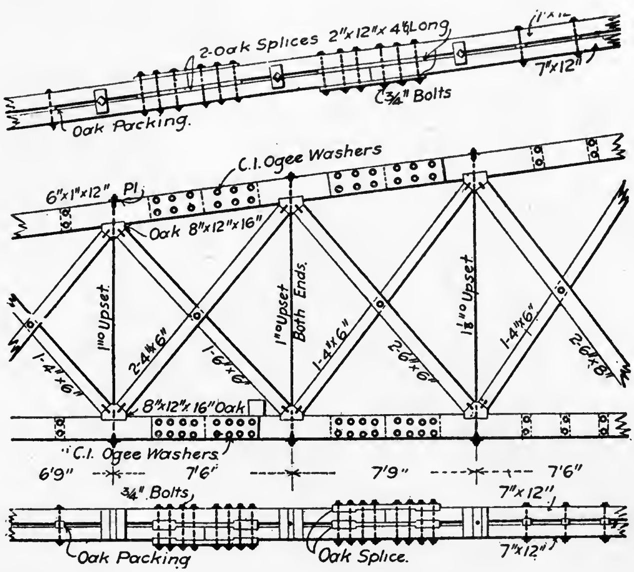


Fig. 36.

skating rink at Cleveland, with wooden arch trusses of 100-ft. span. When provided with automatic sprinklers, cut off walls, and fire extinguishers, slow burning construction with large size timbers, though not fireproof, is considered a good fire risk, for the action of fire on large timbers is slow.

Trusses are easily framed by making chords of several layers of plank spiked together, with main web diagonals of solid timber, and counters of double 2 to 3-in. planks inserted for the sake of better joints, between the layers of plank in the chords. The number of spikes or nails of different size needed at the joints, may be computed from the following table:

TABLE III.—SHEARING VALUE IN LBS. OF NAILED JOINTS.

	Ultimate	Resistance at yield point	
30 d wire nail	460	230	For working unit use half of this last column, or a quarter of the ultimate.
40 d wire nail	560	280	
50 d wire nail	650	325	
60 d wire nail	750	375	
7 in. wire nail, gauge 0	1070	535	
8 in. wire nail, gauge 00	1290	645	

Columns should be of good straight timber without knots, the best kind being Southern pine. They should be bored through

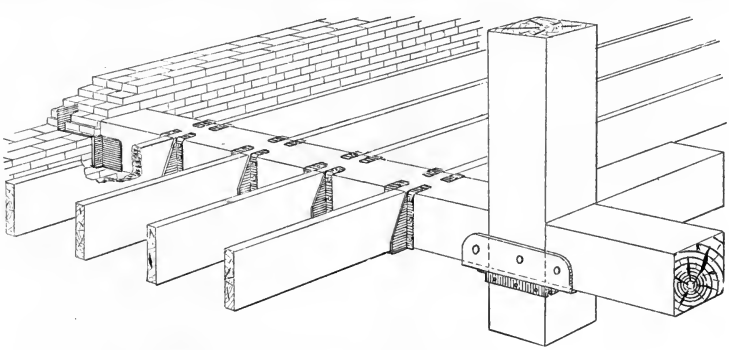


FIG. 37*a*.—Details of timber framing.

the center with a 1½-in. hole and should remain unpainted for about two years. Columns supporting floors must usually be

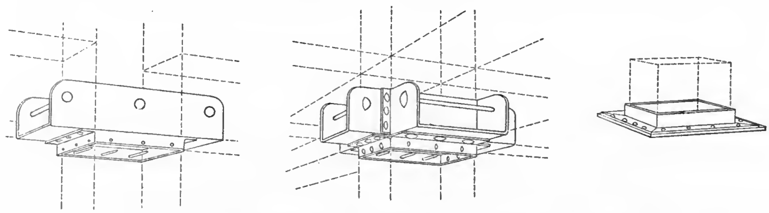
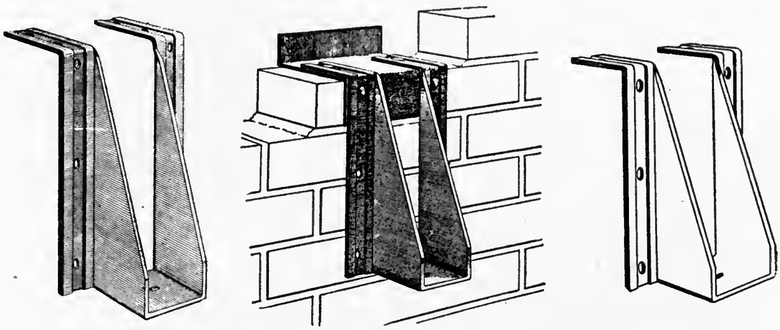


FIG. 37*b*.—Iron caps and base for wooden columns.

spaced not more than 12 to 16 ft. apart, owing to the increasing difficulty in getting greater lengths. Timber columns were often designed with excessive strength and dimensions, but they should now be proportioned by Professor Lanza's formulæ or some other one equally reliable.

Details of column and beam connections are shown in Figs. 37 and 38.

Floor timbers bearing on walls should be anchored thereto with flanged bearing plates, and not as formerly, with bolts passing through the walls fastened outside with washers, because the latter arrangement in case of fire, causes the wall to collapse. An excellent floor is made of 2 by 4, or 2 by 6-in. scantling laid on edge and spiked together, and covered with a wearing surface of 1-in. flooring. (See Wood Floors).



A B C

FIG. 38.—Beam hangers.

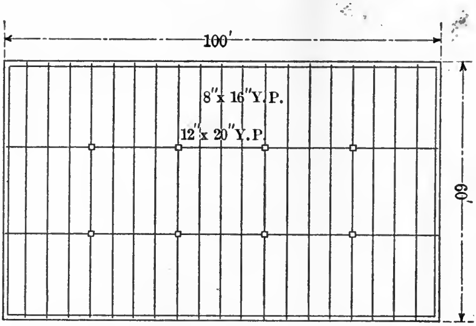
To prevent fire from passing up to other stories, belt towers should be separated from the working floors by brick partitions with fire doors. Without such towers fire was formerly carried up through the building on belts.

Cost of Wood Mill Construction.—Buildings of slow burning wood construction, in widths of about 50 ft. and heights up to five or six stories, cost in the Northern States about as follows:

Number of stories	Cost in cents per square foot of floor area	Cost in cents per cubic foot of contents
3, 4, or 5 stories.......	85 to 95	6.5 to 7.5
2 story................	90 to 100	7.0 to 8.0
1 story................	95 to 105	7.5 to 8.5

These costs do not include plumbing, heating, or elevators, which would increase the cost by 1 to 2 cents per cubic foot in each

case. In country districts where labor is cheap, the cost may be 15 to 20 per cent. less, and in the South, where both labor and materials are 30 to 50 per cent. less than in the North, the cost will be reduced accordingly. Buildings which cost $8\frac{1}{2}$ cents per cubic foot in large cities, have been reproduced in small towns for about 6 cents per cubic foot. Under the most favorable conditions, wood factory buildings in the South, not including the items mentioned above, will cost as low as $4\frac{1}{2}$ to 5 cents per cubic foot. In Georgia and Carolina,



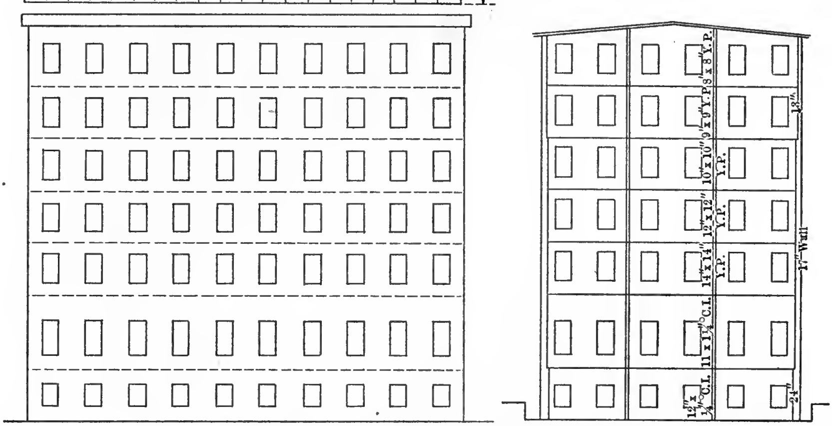


FIG. 39.—Seven story factory at Cincinnati, Ohio.

two-story cotton mills have occasionally been erected at prices of 45 to 60 cents per square foot of floor area. The building costs given above for northern latitudes are quite low, and wooden buildings of mill construction with floorloads of 200 lb. per square foot, have sometimes cost from \$1.40 to \$1.60 per square foot.

A slow burning wood mill building (Fig. 39) designed in 1905 by the writer, with a basement and seven stories, and a total floor area of 38,700 sq. ft., cost for the structure only, with foundations, floors and framing, but without equipment, 96 cents per square foot of floor area, and 7.7 cents per cubic foot

of contents. It was proportioned for a live load of 200 lb. per foot on the floors. Another six-story building[1] 60 ft. wide and 100 ft. long, for a floor load of only 100 lb., cost 83 cents per square foot, or 6.2 cents per cubic foot, the cost of the floors and columns only, being 27 cents per square foot of floor area.

A table giving the cost of a miscellaneous lot of wood buildings, reproduced from a report of the National Association of Cement Users for 1909, is as follows:

TABLE IV.—COST OF BUILDINGS OF WOOD MILL CONSTRUCTION

	Cost	Vol. cu. ft.	Floor area sq. ft.	Unit cost	
				cu. ft.	sq. ft.
Mill, Boston	$ 66,516	544,788	44,172	.122	1.51
Warehouse, Boston	337,000	2,808,850	....	.12	....
Mill, Boston	113,288	1,271,300	129,920	.0891	.875
Storehouse, Nashua	101,098	1,714,450	168,696	.059	.60
Mill, Easthampton	90,706	1,622,128	152,200	.056	.60
Mill, Fitchburg	72,048	1,331,200	83,200	.054	.865
Mill, Woonsocket	85,754	1,752,600	81,500	.048	1.05
Mill, Centerville	122,128	2,641,000	98,059	.046	1.25
Mill, Pawtucket	94,341	2,036,700	174,000	.046	.542
Mill, Fitchburg	129,400	2,867,500	157,700	.045	.82
Average cost	....	....	....	.069	.90

From this table it appears that the cost of these buildings per cubic foot varies from 4½ to 12 cents, with an average of about 7 cents, and the corresponding cost per square foot of floor area, from 54 cents to $1.50, with an average of 90 cents.

The cost is affected also by the degree of duplication which is carried out, and by the simplicity of the framing. It is usually economical to specify lengths and sizes which are easily obtainable, for if extra ones are desired, the cost will be increased with accompanying delay. As previously stated, the cost of wood framing depends upon the location. Timber which would cost $28 to $30 per M at Chicago, might be purchased in Oregon for about half those prices, the delivered price being a combination of the production cost and profit, with freight charges added.

Corresponding charts for the cost of wood mill buildings, prepared by C. T. Main of Boston, are as follows:

[1] H. G. Tyrrell, in *Carpentry and Building*, Nov., 1905.

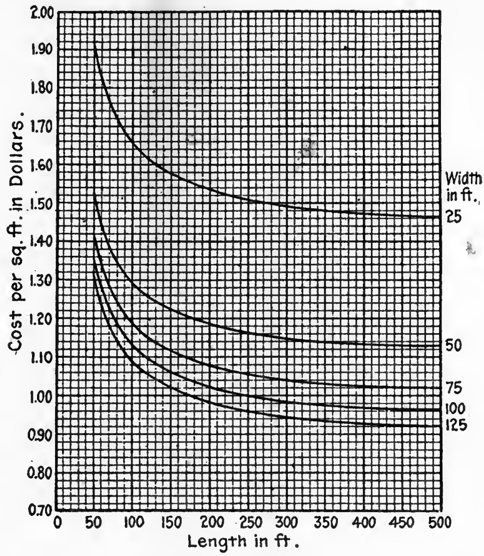


FIG. 40.—Cost diagram for brick mill buildings, one-story.

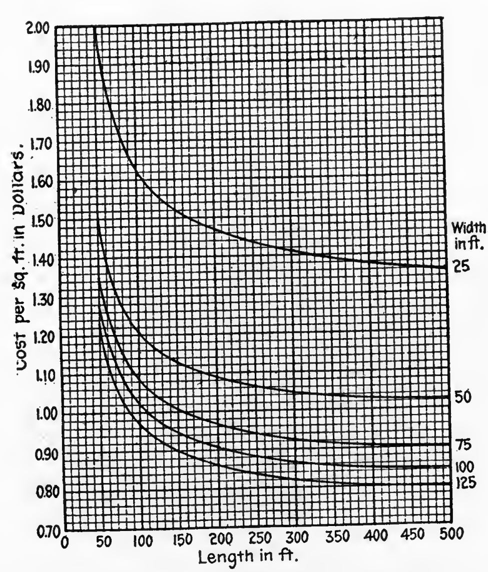


FIG. 41.—Cost diagram for brick mill buildings, two-story.

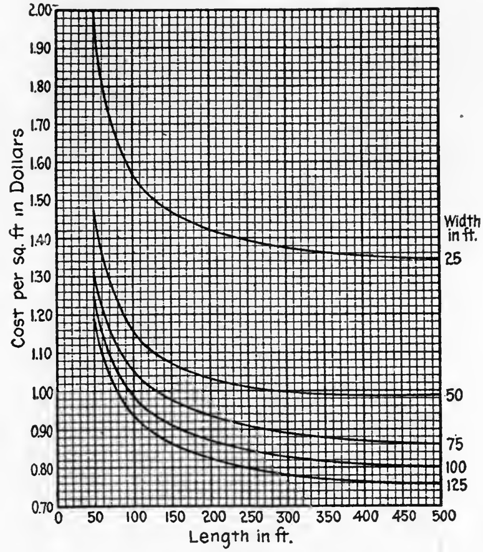


FIG. 42.—Cost diagram for brick mill buildings, three-story.

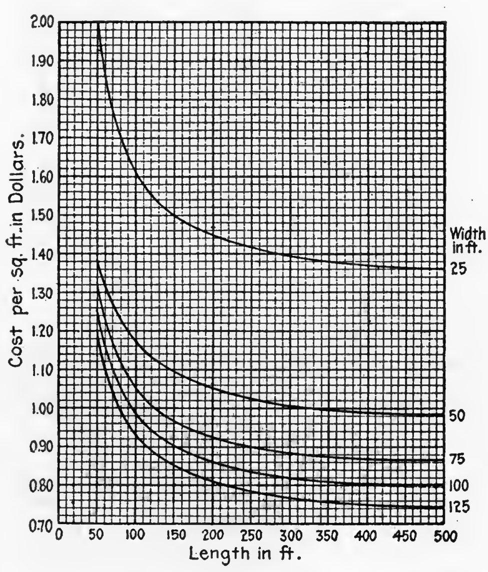


FIG. 43.—Cost diagram for brick mill buildings, four-story.

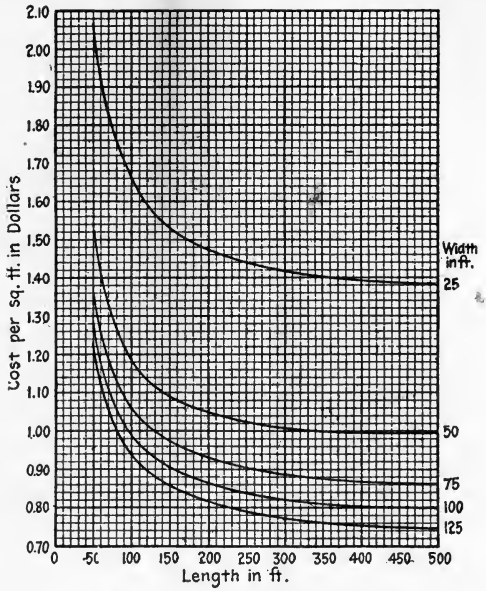


Fig. 44.—Cost diagram for brick mill buildings, five-story.

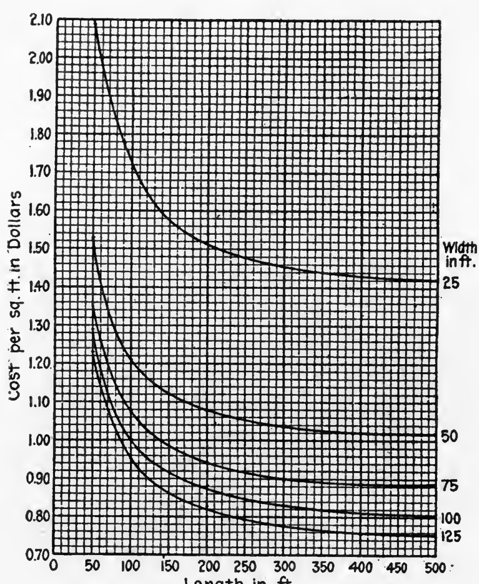


Fig. 45.—Cost diagram for brick mill buildings, six-story.

Metal Framing.—Steel framing can be definitely proportioned for either short or long spans, with connections of any desired strength, and it can be quickly erected. It is not fireproof and deteriorates rapidly from rust when not painted or not otherwise protected. It has been conclusively proven by great conflagrations such as those at San Francisco and Baltimore, that steel is not fireproof or permanent even when enclosed, for the covering will break off, leaving the metal exposed. At a temperature of 1000° F., steel framing will collapse under load, resulting in complete ruin. A casing or enclosure of 1/2 to 2 in. of reinforced concrete gives partial protection, but is of little use when fire has gained much headway. Fireproofing with terra cotta blocks is of still smaller value, as the blocks are brittle and will shake to pieces. Steel framing is not considered even as choice a fire risk as heavy timbers, and it costs including maintenance, much more than either timber or reinforced concrete.

Cast iron columns are often preferable to steel, for they occupy smaller space and have a better appearance, but they fail quickly in fire when cooled with a jet of water, though not so quickly as steel. Unless the casting process is carefully done, the core is liable to float, making the metal thinner on one side of the columns than on the other, and in this condition they may be unsafe and liable to fail under lateral blows or pressure. Defects of this kind can be detected only by measuring the thickness with a long arm calipers, but danger can be avoided by using columns of wrought-iron pipe, the strength of which can be increased by filling them with fine concrete. Rolled steel columns of Bethelehem shape (Fig. 46), save the expense of punching and riveting, and connections to them are easily made, but this saving is somewhat offset by their greater pound price.

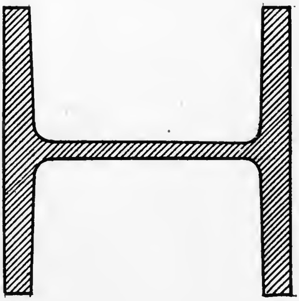


Fig. 46.

Metal frames are preserved in several ways, some of which are: (1) painting, (2) Bower-Barff oxidation, (3) zinc or lead coating, and (4) enameling. In the Bower-Barff process, superheated steam is passed over metal while it is red hot, when oxygen combines with the metal, forming an oxide coating which prevents any further oxidation.

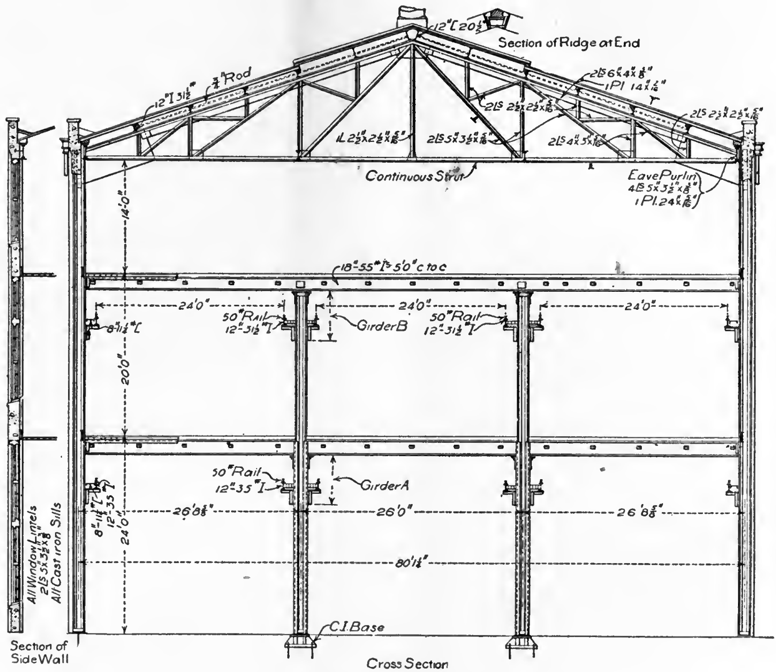


FIG. 47.—Machine shop at Lynn, Mass.

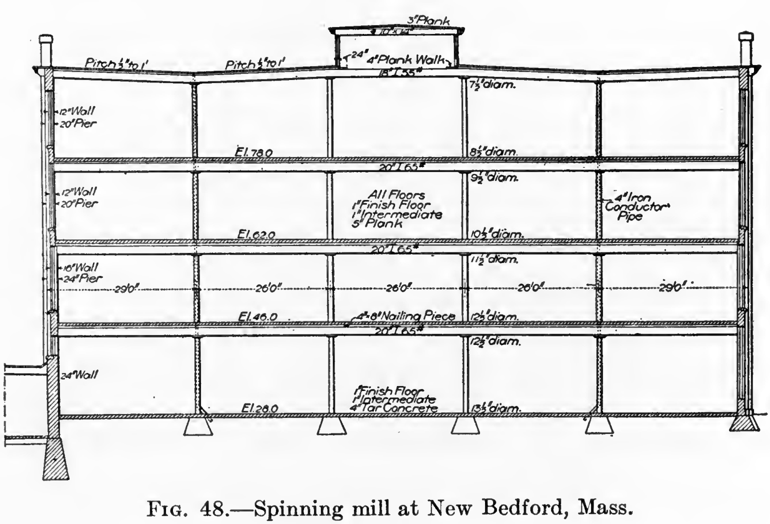


FIG. 48.—Spinning mill at New Bedford, Mass.

A three-story shop with metal framing and steel columns is shown in Fig. 47, and a four-story shop of unusual width in Fig. 48. Fig. 49 is a typical floor plan of the ten-story Everard warehouse at 10th and Washington streets, New York, plans for

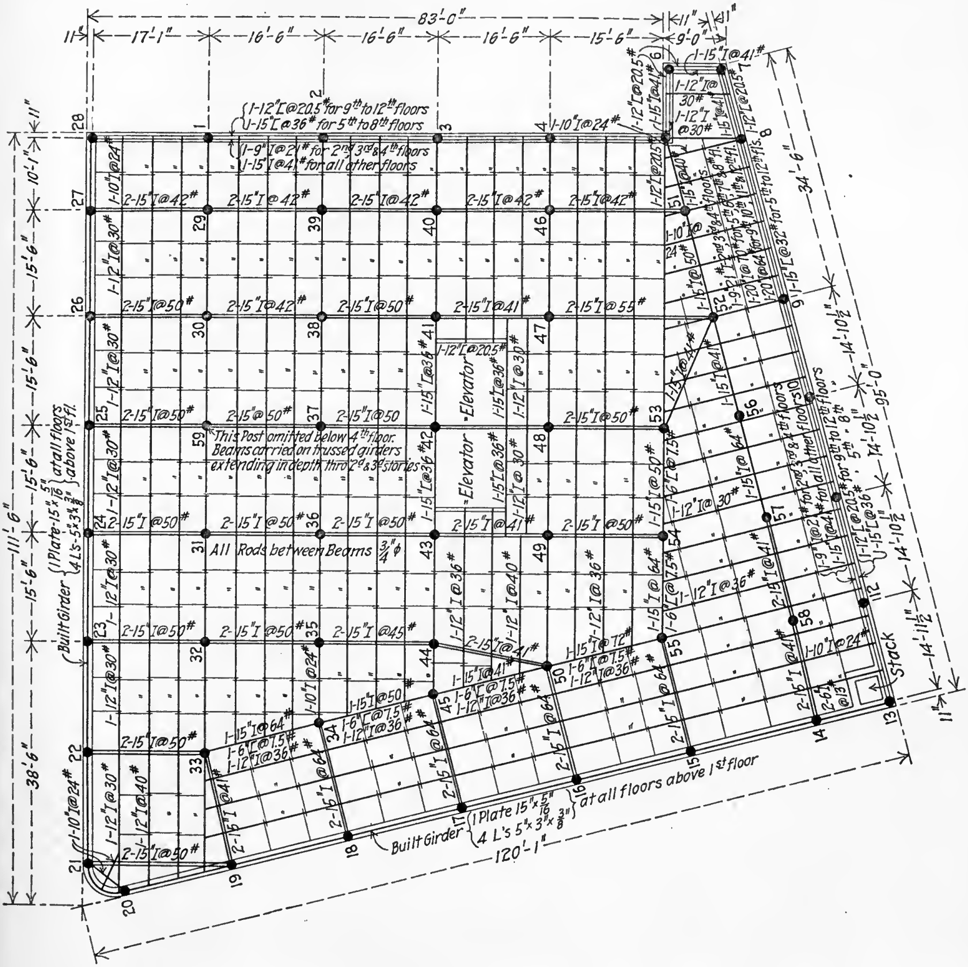


Fig. 49.—Typical floor plan, Everard warehouse, New York City.

which were made by the writer in 1896, and the accompanying table gives a schedule of the columns. In order to add stiffness to the frame, the column sections generally extend through at least two stories, and column splices are staggered, some splices

NOTE.—The column schedule given herewith is much more lengthy than was intended by the author, but it may be valuable to students and others not regularly engaged in designing building frames, and especially so as such data is not generally found in other books.

SCHEDULE OF COLUMNS

Floor	Height between floors	Col. No. 1	Col. No. 2	Col. No. 3	Col. No. 4
Twelfth..	....	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	Same as Col. No. 1.	Same as Col. No. 1.	Same as Col. No. 1.
Eleventh.	10′ 3″	4Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$			
Tenth....	10′ 3″				
Ninth....	10′ 3″	4 Zs. $5\times\frac{3}{8}''$ 1 Pl. $7\times\frac{3}{8}''$			
Eighth...	10′ 3″				
Seventh..	10′ 3″	4 Zs. $6\times\frac{1}{2}''$ 1 Pl. $8\times\frac{1}{2}''$			
Sixth....	10′ 3″				
Fifth.....	10′ 3″	4 Zs. $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$			
Fourth...	10′ 3″				
Third....	10′ 3″	4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$			
Second...	10′ 3″				
First.....	12′ 0″	2 Pls. $14\times\frac{3}{8}''$ 4 Zs. $6\times\frac{3}{4}''$ 1 Pl. $8\times\frac{3}{4}''$			
Cellar....	12′ 6″	1 Pl. $8\times\frac{3}{4}''$ 2 Pls. $14\times\frac{5}{8}''$ 4 Zs $6\times\frac{3}{4}''$			

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 5	Col. No. 6	Col. No. 7	Col. No. 8
Twelfth..	....	Same as Col. No. 1.	4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$	Same as Col. No. 6.	4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$
Eleventh:	10′ 3″		1 Pl. $6\times\frac{1}{4}''$		4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$
Tenth....	10′ 3″		4 Z $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		
Ninth....	10′ 3″				4 Zs. $4\times\frac{3}{8}''$ 1 Pl. $6\frac{1}{2}\times\frac{3}{8}''$
Eighth...	10′ 3″				
Seventh..	10′ 3″				4 Zs. $6\times\frac{7}{16}''$ 1 Pl. $8\times\frac{7}{16}''$
Sixth....	10′ 3″		4 Zs. $4\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$		
Fifth.....	10′ 3″				4 Zs. $6\times\frac{5}{8}''$ 1 Pl. $8\times\frac{5}{8}''$
Fourth...	10′ 3″		4 Zs. $4\times\frac{5}{16}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$		
Third....	10′ 3″				4 Zs. $6\times\frac{13}{16}''$ 1 Pl. $8\times\frac{13}{16}''$
Second...	10′ 3″		4 Zs. $5\times\frac{3}{8}''$ 1 Pl. $7\times\frac{3}{8}''$		
First.....	12′ 0″				4 Zs $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$ 2 Pls. $14\times\frac{3}{8}''$
Cellar....	12′ 6″				4 Zs. $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$ 2 Pl. $14\times\frac{9}{16}''$

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 9	Col. No. 10	Col. No. 11	Col. No. 12
Twelfth..	....	4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$	4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	Same as Col. No. 10.	Same as Col. No. 10.
Eleventh.	10′ 3″	4 Zs. $4\times\frac{1}{4}''$	4 Zs. $3\times\frac{1}{4}''$		
Tenth....	10′ 3″	1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$	1 Pl. $6\times\frac{1}{4}''$		
Ninth....	10′ 3″	4 Zs. $6\times\frac{3}{8}''$	4 Zs. $5\times\frac{5}{16}''$		
Eighth...	10′ 3″	1 Pl. $8\times\frac{3}{8}''$	1 Pl. $7\times\frac{5}{16}''$		
Seventh..	10′ 3″	4 Zs. $6\times\frac{9}{16}''$	4 Zs. $6\times\frac{7}{16}''$		
Sixth....	10′ 3″	1 Pl. $8\times\frac{9}{16}''$	1 Pl. $8\times\frac{7}{16}''$		
Fifth.....	10′ 3″	4 Zs. $6\times\frac{13}{16}''$	4 Zs. $6\times\frac{5}{8}''$		
Fourth...	10′ 3″	1 Pl. $8\times\frac{13}{16}''$	1 Pl. $8\times\frac{5}{8}''$		
Third....	10′ 3″	4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{13}{16}''$		
Second...	10′ 3″	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$	1 Pl. $8\times\frac{13}{16}''$		
First.....	12′ 0″	2 Pls. $14\times\frac{3}{8}''$ 1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{7}{8}''$		
Cellar....	12′ 6″	1Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{1}{2}''$ 4 Zs $6\times\frac{7}{8}$	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$		

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 13	Col. No. 14	Col. No. 15	Col. No. 16
Twelfth..	....	4Ls.$2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$	
Eleventh:	10′ 3″		4 Zs. $4\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$	4 Zs. $4\times\frac{5}{16}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$	
Tenth....	10′ 3″	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$			
Ninth....	10′ 3″		4 Zs. $5\times\frac{3}{8}''$ 1 Pl. $7\times\frac{3}{8}''$	4 Zs. $6\times\frac{7}{16}''$ 1 Pl. $8\times\frac{7}{16}''$	
Eighth...	10′ 3″	4 Zs. $4\times\frac{5}{16}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$			
Seventh..	10′ 3″		4 Zs. $6\times\frac{1}{2}''$ 1 Pl. $8\times\frac{1}{2}''$	4 Zs. $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$	Same as Col. No. 15.
Sixth....	10′ 3″	4 Zs. $5\times\frac{3}{8}''$ 1 Pl. $7\times\frac{3}{8}''$			
Fifth.....	10′ 3″		4 Zs. $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$	4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$	
Fourth...	10′ 3″	4 Zs. $6\times\frac{7}{16}''$ 1 Pl. $8\times\frac{7}{16}''$			
Third....	10′ 3″		4 Zs. $6\times\frac{13}{16}''$ 1 Pl. $8\times\frac{13}{16}''$	2 Pls. $14\times\frac{7}{16}''$ 1 Pl. $8\times\frac{3}{4}''$ 4 Zs. $6\times\frac{3}{4}''$	
Second...	10′ 3″	4 Zs. $6\times\frac{9}{16}''$ 1 Pl. $8\times\frac{9}{16}''$		1 Pl. $8\times\frac{3}{4}''$ 2 Pls. $14\times\frac{9}{16}''$ 4 Zs. $6\times\frac{3}{4}''$	
First.....	12′ 0″		4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{3}{8}''$	2 Pls. $16\times\frac{1}{2}''$ 1 Pl. $10\times1''$ 4 Zs. $6\times\frac{7}{8}''$	
Cellar....	12′ 6″	4 Zs. $6\times\frac{11}{16}''$ 1 Pl. $8\times\frac{11}{16}''$		1 Pl. $10\times1''$ 2 Pls. $16\times\frac{3}{4}''$ 4 Zs. $6\times\frac{7}{8}''$	

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 17	Col. No. 18	Col. No. 19	Col. No. 20
Twelfth..	....			4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$ 1 Pl. $7\times\frac{5}{16}''$	4Ls.$2\frac{1}{2}\times 2\times\frac{1}{4}''$
Eleventh:	10′ 3″			4 Zs. $5\times\frac{5}{16}''$	1 Pl. $6\times\frac{1}{4}''$
Tenth....	10′ 3″			1 Pl. $7\times\frac{5}{16}''$	4 Zs. $3\times\frac{1}{4}''$
Ninth....	10′ 3″			4 Zs. $6\times\frac{1}{2}''$	1 Pl. $6\times\frac{1}{4}''$
Eighth...	10′ 3″			1 Pl. $8\times\frac{1}{2}''$	4 Zs. $3\times\frac{1}{4}''$
Seventh..	10′ 3″			4 Zs. $6\times\frac{3}{4}''$	1 Pl. $6\times\frac{1}{4}''$
Sixth....	10′ 3″	Same as Col. No. 15.	Same as Col. No. 15.	1 Pl. $8\times\frac{3}{4}''$	4 Zs. $4\times\frac{5}{16}''$
Fifth.....	10′ 3″			4 Zs. $6\times\frac{7}{8}''$	1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$
Fourth...	10′ 3″			1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{3}{8}''$	4 Zs. $5\times\frac{5}{16}''$
Third....	10′ 3″			2 Pls. $14\times\frac{7}{16}''$ 1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $7\times\frac{5}{16}''$
Second...	10′ 3″			1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $5\times\frac{5}{16}''$
First.....	12′ 0″			2 Pls. $18\times\frac{1}{2}''$ 1 Pl. $12\times 1''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $7\times\frac{5}{16}''$
Cellar....	12′ 6″			1 Pl. $12\times 1''$ 2 Pls. $18\times\frac{3}{4}''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $5\times\frac{3}{8}''$ 1 Pl. $7\times\frac{3}{8}''$

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 21	Col. No. 22	Col. No. 23	Col. No. 24
Twelfth..	....	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$		
Eleventh	10′ 3″	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	4 Zs. $4\times\frac{5}{16}''$		
Tenth....	10′ 3″	4 Zs. $5\times\frac{3}{8}''$	1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$		
Ninth....	10′ 3″	1 Pl. $7\times\frac{3}{8}''$	4 Zs. $5\times\frac{1}{2}''$		
Eighth...	10′ 3″	4 Zs. $6\times\frac{1}{2}''$	1 Pl. $7\times\frac{1}{2}''$		
Seventh..	10′ 3″	1 Pl. $8\times\frac{1}{2}''$	4 Zs. $6\times\frac{5}{8}''$		
Sixth....	10′ 3″	4 Zs. $6\times\frac{11}{16}''$	1 Pl. $8\times\frac{5}{8}''$	Same as Col. No. 22.	Same as Col. No. 22.
Fifth.....	10′ 3″	1 Pl. $8\times\frac{11}{16}''$	4 Zs. $6\times\frac{13}{16}''$		
Fourth...	10′ 3″	4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{13}{16}''$		
Third....	10′ 3″	1 Pl. $8\times\frac{7}{8}''$	2 Pls. $14\times\frac{5}{16}''$ 1 Pl. $8\times\frac{3}{4}''$ 4 Zs. $6\times\frac{3}{4}''$		
Second...	10′ 3″	2 Pls. $14\times\frac{3}{8}''$ 1 Pl. $8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$	1 Pl. $8\times\frac{3}{4}''$ 2 Pls. $14\times\frac{7}{16}''$ 4 Zs. $6\times\frac{3}{4}''$		
First.....	12′ 0″	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{7}{16}''$ 4 Zs. $6\times\frac{13}{16}''$	2 Pls. $14\times\frac{7}{16}''$ 1 Pl. $8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$		
Cellar....	12′ 6″	2 Pls. $14\times\frac{11}{16}''$ 4 Zs. $6\times\frac{13}{16}''$ 1 Pl. $8\times\frac{13}{16}''$	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{3}{4}''$ 4 Zs. $6\times\frac{13}{16}''$		

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 25	Col. No. 26	Col. No. 27	Col. No. 28
Twelfth..	....				
Eleventh	10′ 3″				
Tenth....	10′ 3″				
Ninth....	10′ 3″				
Eighth...	10′ 3″				
Seventh..	10′ 3″				
Sixth....	10′ 3″	Same as Col. No. 22.	Same as Col. No. 22.	Same as Col. No. 14.	Same as Col. No. 13.
Fifth.....	10′ 3″				
Fourth...	10′ 3″				
Third....	10′ 3″	2 Pls. 24×$\frac{7}{16}$″ 2 Pls. 26×$\frac{5}{8}$″ 4 Ls. 6×4×$\frac{5}{8}$″ 2 Pls. 13×$\frac{5}{8}$″			
Second...	10′ 3″	2 Pls. 24×$\frac{1}{2}$″ 2 Pls. 26×$\frac{5}{8}$″ 4 Ls. 6×4×$\frac{5}{8}$″ 2 Pls. 13×$\frac{5}{8}$″			
First.....	12′ 0″	2 Pls. 24×$\frac{9}{16}$″ 2 Pls. 26×$\frac{5}{8}$″ 4 Ls. 6×4×$\frac{5}{8}$″ 2 Pls. 13×$\frac{5}{8}$″			
Cellar....	12′ 6″	2 Pls. 24×$\frac{3}{4}$″ 2 Pls. 26×$\frac{5}{8}$″ 4 Ls. 6×4×$\frac{5}{8}$″ 2 Pls. 13×$\frac{5}{8}$″			

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 29	Col. No. 30	Col. No. 31	Col. No. 32
Twelfth..	....	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$		
Eleventh	10′ 3″	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	4 Zs. $4\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$		
Tenth....	10′ 3″	4 Zs. $6\times\frac{3}{8}''$	4 Zs. $6\times\frac{7}{16}''$		
Ninth....	10′ 3″	1 Pl. $8\times\frac{3}{8}''$	1 Pl. $8\times\frac{7}{16}''$		
Eighth...	10′ 3″	4 Zs. $6\times\frac{1}{2}''$	4 Zs. $6\times\frac{3}{4}''$		
Seventh..	10′ 3″	1 Pl. $8\times\frac{1}{2}''$	1 Pl. $8\times\frac{3}{4}''$		
Sixth....	10′ 3″	4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{7}{8}''$	Same as Col. No. 30.	Same as Col. No. 30.
Fifth.....	10′ 3″	1 Pl. $8\times\frac{7}{8}''$	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$		
Fourth...	10′ 3″	2 Pls. $14\times\frac{5}{16}''$ 1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	2 Pls. $14\times\frac{9}{16}''$ 1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$		
Third....	10′ 3″	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{3}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{13}{16}''$ 4 Zs. $6\times\frac{7}{8}''$		
Second...	10′ 3″	2 Pls. $16\times\frac{7}{16}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $10\times1''$	2 Pls. $18\times\frac{3}{4}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $12\times1''$		
First.....	12′ 0″	2 Pls. $16\times\frac{5}{8}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $10\times1''$	2 Pls. $18\times\frac{15}{16}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $12\times1''$		
Cellar....	12′ 6″	2 Pls. $16\times\frac{13}{16}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $10\times1''$	2 Pls. $18\times1\frac{1}{8}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $12\times1''$		

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 33	Col. No. 34	Col. No. 35	Col. No. 36
Twelfth..	....		4 Ls. $2\frac{1}{2} \times 2 \times \frac{1}{4}''$ 1 Pl. $6\frac{1}{2} \times \frac{1}{4}''$	4 Ls. $2\frac{1}{2} \times 2 \times \frac{1}{4}''$ 1 Pl. $7 \times \frac{5}{16}''$	4 Zs. $3 \times \frac{1}{4}''$ 1 Pl. $6 \times \frac{1}{4}''$
Eleventh	10′ 3″		4 Zs. $4 \times \frac{1}{4}''$ 1 Pl. $6\frac{1}{2} \times \frac{1}{4}''$	4 Zs. $5 \times \frac{5}{16}''$	4 Zs. $6 \times \frac{3}{8}''$
Tenth....	10′ 3″		4 Zs. $6 \times \frac{7}{16}''$	1 Pl. $7 \times \frac{5}{16}''$	1 Pl. $8 \times \frac{3}{8}''$
Ninth....	10′ 3″		1 Pl. $8 \times \frac{7}{16}''$	4 Zs. $6 \times \frac{1}{2}''$	4 Zs. $6 \times \frac{11}{16}''$
Eighth...	10′ 3″		4 Zs. $6 \times \frac{11}{16}''$	1 Pl. $8 \times \frac{1}{2}''$	1 Pl. $8 \times \frac{11}{16}''$
Seventh..	10′ 3″		1 Pl. $8 \times \frac{11}{16}''$	4 Zs. $6 \times \frac{13}{16}''$	4 Zs. $6 \times \frac{13}{16}''$
Sixth....	10′ 3″	Same as Col. No. 30.	2 Pls. $14 \times \frac{5}{16}'$, 1 Pl. $8 \times \frac{3}{4}''$ 4 Zs. $6 \times \frac{3}{4}''$	1 Pl. $8 \times \frac{13}{16}''$	1 Pl. $8 \times \frac{13}{16}''$ 2 Pls. $14 \times \frac{5}{16}''$
Fifth.....	10′ 3″		1 Pl. $8 \times \frac{3}{4}''$ 2 Pls. $14 \times \frac{7}{16}''$ 4 Zs. $6 \times \frac{3}{4}''$	4 Zs. $6 \times \frac{7}{8}''$	2 Pls. $14 \times \frac{7}{16}''$ $1-8 \times \frac{7}{8}''$ 4 Zs. $6 \times \frac{7}{8}''$
Fourth...	10′ 3″		2 Pls. $14 \times \frac{7}{16}''$ 1 Pl. $8 \times \frac{7}{8}''$ 4 Zs. $6 \times \frac{7}{8}''$	1 Pl. $8 \times \frac{7}{8}''$ 2 Pls. $14 \times \frac{5}{16}''$	1 Pl. $8 \times \frac{7}{8}''$ 2 Pls. $14 \times \frac{11}{16}''$ 4 Zs. $6 \times \frac{7}{8}''$
Third....	10′ 3″		1 Pl. $8 \times \frac{7}{8}''$ 2 Pls. $14 \times \frac{11}{16}''$ 4 Zs. $6 \times \frac{7}{8}''$	2 Pls. $14 \times \frac{1}{2}''$ $1-8 \times \frac{7}{8}''$ 4 Zs. $6 \times \frac{7}{8}''$	2 Pls. $18 \times \frac{5}{8}''$ $1-12 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$
Second...	10′ 3″		2 Pls. $18 \times \frac{5}{8}''$ 4 Zs. $6 \times \frac{7}{8}''$ 1 Pl. $12 \times 1''$	1 Pl. $8 \times \frac{7}{8}''$ 2 Pls. $14 \times \frac{3}{4}''$ 4 Zs. $6 \times \frac{7}{8}''$	1 Pl. $12 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$ 2 Pls. $18 \times \frac{13}{16}''$
First.....	12′ 0″		2 Pls. $18 \times \frac{13}{16}''$ 4 Zs. $6 \times \frac{7}{8}''$ 1 Pl. $12 \times 1''$	2 Pls. $18 \times \frac{5}{8}''$ 1 Pl. $12 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$	2 Pls. $20 \times \frac{7}{8}''$ $1-14 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$
Cellar....	12′ 6″		2 Pls. $18 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$ $1-12 \times 1''$	1 Pl. $12 \times 1''$ 2 Pls. $18 \times \frac{13}{16}''$ 4 Zs. $6 \times \frac{7}{8}''$	1 Pl. $14 \times 1''$ 4 Zs. $6 \times \frac{7}{8}''$ 2 Pls. $20 \times 1\frac{1}{16}''$

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 37	Col. No. 38	Col. No. 39	Col. No. 40
Twelfth..	....	4 Zs. $4\times\frac{3}{8}''$			
Eleventh	10′ 3″	1 Pl. $6\frac{1}{2}\times\frac{3}{8}''$			
Tenth....	10′ 3″	4 Zs. $6\times\frac{9}{16}''$			
Ninth....	10′ 3″	1 Pl. $8\times\frac{9}{16}''$			
Eighth...	10′ 3″	4 Zs. $6\times\frac{7}{8}''$			
Seventh..	10′ 3″	1 Pl. $8\times\frac{7}{8}''$			
Sixth....	10′ 3″	4 Zs. $6\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$ $1-8\times\frac{7}{8}''$	Same as Col. No. 36.	Same as Col. No. 29.	Same as Col. No. 29.
Fifth.....	10′ 3″	2 Pls. $14\times\frac{1}{2}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$			
Fourth...	10′ 3″	4 Zs. $6\times\frac{7}{8}''$ $1-8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{13}{16}''$			
Third....	10′ 3″	2 Pl. $24\times\frac{7}{16}''$ 2 Pl. $24\times\frac{3}{4}''$ 4 L. $6\times4\times\frac{3}{4}''$ 2 Pl. $11\times\frac{3}{4}''$ 2 Pl. $22\times\frac{1}{2}''$			
Second...	10′ 3″	2 Pls. $24\times\frac{9}{16}''$ 2 Pl. $24\times\frac{3}{4}''$ 4 L. $6\times4\times\frac{3}{4}''$ 2 Pl. $11\times\frac{3}{4}''$ 2 Pl. $22\times\frac{1}{2}''$			
First.....	12′ 0″	2 Pl. $24\times\frac{3}{4}''$ 2 Pl. $24\times\frac{3}{4}''$ 4 L. $6\times4\times\frac{3}{4}''$ 2 Pl. $11\times\frac{3}{4}''$ 2 Pl. $22\times\frac{1}{2}''$			
Cellar....	12′ 6″	2 Pl. $24\times\frac{7}{8}''$ 2 Pl. $24\times\frac{3}{4}''$ 4 L. $6\times4\times\frac{3}{4}''$ 2 Pl. $11\times\frac{3}{4}''$ 2 Pl. $22\times\frac{1}{2}''$			

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 41	Col. No. 42	Col. No. 43	Col. No. 44
Twelfth..	....	4 Zs. $4\times\frac{5}{16}''$	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$
Eleventh	10′ 3″	1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$	4 Zs. $5\times\frac{3}{8}''$		4 Zs. $4\times\frac{5}{16}''$
Tenth....	10′ 3″	4 Zs. $6\times\frac{7}{16}''$	1 Pl. $7\times\frac{3}{8}''$		1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$
Ninth....	10′ 3″	1 Pl. $8\times\frac{7}{16}''$	4 Zs. $6\times\frac{7}{16}''$		4 Zs. $6\times\frac{7}{16}''$
Eighth...	10′ 3″	4 Zs. $6\times\frac{11}{16}''$	1 Pl. $8\times\frac{7}{16}''$		1 Pl. $8\times\frac{7}{16}''$
Seventh..	10′ 3″	1 Pl. $8\times\frac{11}{16}''$	4 Zs. $6\times\frac{5}{8}''$		4 Zs. $6\times\frac{11}{16}''$
Sixth....	10′ 3″	4 Zs. $6\times\frac{13}{16}''$	1 Pl. $8\times\frac{5}{8}''$	Same as Col. No. 41.	1 Pl. $8\times\frac{11}{16}''$
Fifth.....	10′ 3″	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{1}{2}''$	4 Zs. $6\times\frac{13}{16}''$		4 Zs. $8\times\frac{13}{16}''$
Fourth...	10′ 3″	2 Pls. $14\times\frac{3}{8}''$ 1 Pl. $6\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{13}{16}''$		1 Pl. $6\times\frac{13}{16}''$ 2 Pls .$14\times\frac{5}{16}''$
Third....	10′ 3″	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{7}{8}''$		2 Pls. $14\times\frac{3}{8}''$ $1-8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$
Second...	10′ 3″	2 Pls. $18\times\frac{1}{2}''$ $1-12\times1''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$		1 Pl. $8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$ 2 Pls. $14\times\frac{5}{8}''$
First.....	12′ 0″	1 Pl. $12\times1''$ 2 Pls. $18\times\frac{11}{16}''$ 4 Zs. $6\times\frac{7}{8}''$	2 Pls. $14\times\frac{5}{16}''$ 1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$		$1-6\times\frac{7}{8}''$ 2 Pls. $14\times\frac{11}{16}''$ 4 Zs. $6\times\frac{7}{8}''$
Cellar....	12′ 6″	1 Pl. $12\times1''$ 2 Pls. $18\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{3}{8}''$ 4 Zs. $6\times\frac{7}{8}''$		1 Pl. $8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$ 2 Pls. $14\times\frac{7}{8}''$

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 45	Col. No. 46	Col. No. 47	Col. No. 48
Twelfth..	....	4 Ls. $2\frac{1}{2}\times 2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		4 Zs. $4\times\frac{1}{4}''$	
Eleventh:	10′ 3″	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		1 Pl. $6\frac{1}{2}\times\frac{1}{4}''$	
Tenth....	10′ 3″	4 Zs. $5\times\frac{3}{8}''$		4 Zs. $5\times\frac{9}{16}''$	
Ninth....	10′ 3″	1 Pl. $7\times\frac{3}{8}''$		1 Pl. $7\times\frac{9}{16}''$	
Eighth...	10′ 3″	4 Zs. $6\times\frac{9}{16}''$		4 Zs. $6\times\frac{13}{16}''$	
Seventh..	10′ 3″	1 Pl. $8\times\frac{9}{16}''$		1 Pl. $8\times\frac{13}{16}''$	
Sixth....	10′ 3″	4 Zs. $6\times\frac{13}{16}''$	Same as Col. No. 29.	$2-14\times\frac{3}{8}''$ $1-8\times\frac{3}{4}''$ 4 Zs. $6\times\frac{3}{4}''$	Same as Col. No. 34.
Fifth.....	10′ 3″	1 Pl. $8\times\frac{13}{16}''$		1 Pl. $8\times\frac{3}{4}''$ 2 Pls. $14\times\frac{11}{16}''$ 4 Zs. $6\times\frac{3}{4}''$	
Fourth...	10′ 3″	2 Pls. $14\times\frac{5}{16}''$ $1-8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$		2Pls. $16\times\frac{1}{2}''$ $10\times 1''$ 4 Zs. $6\times\frac{7}{8}''$	
Third....	10′ 3″	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{3}{8}''$ 4 Zs. $6\times\frac{13}{16}''$		1 Pl. $10\times 1''$ 2 Pls. $16\times\frac{3}{4}''$ 4 Zs. $6\times\frac{7}{8}''$	
Second...	10′ 3″	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{1}{2}''$ 4 Zs. $6\times\frac{7}{8}''$		1 Pl. $14\times 1''$ 2 Pls. $20\times\frac{3}{4}''$ 4 Zs. $6\times\frac{7}{8}''$	
First.....	12′ 0″	1 Pl. $8\times\frac{7}{8}''$ 4Zs. $6\times\frac{7}{8}''$ 2 Pls. $14\times\frac{1}{16}''$		1 Pl. $14\times 1''$ 2 Pls. $20\times\frac{15}{16}''$ 4 Zs. $6\times\frac{7}{8}''$	
Cellar....	12′ 6″	2 Pls. $14\times\frac{7}{8}''$ $1-8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$		1 Pl. $14\times 1''$ 2 Pls. $20\times 1\frac{1}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 49	Col. No. 50	Col. No. 51	Col. No. 52
Twelfth..	....		4 Zs. $4\times\frac{5}{16}''$	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}$ 1 Pl. $6\times\frac{1}{4}''$	
Eleventh	10′ 3″		1 Pl. $6\frac{1}{2}\times\frac{5}{16}''$	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	
Tenth....	10′ 3″		4 Zs. $6\times\frac{9}{16}''$	4 Zs. $5\times\frac{3}{8}''$	
Ninth....	10′ 3″		1 Pl. $8\times\frac{9}{16}''$	1 Pl. $7\times\frac{3}{8}''$	
Eighth...	10′ 3″		4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{1}{2}''$	
Seventh..	10′ 3″	Same as Col. No. 47.	1 Pl. $8\times\frac{7}{8}''$	1 Pl. $8\times\frac{1}{2}''$	Same as Col. No. 30.
Sixth....	10′ 3″		2 Pls. $14\times\frac{3}{8}''$ $1-8\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{3}{4}''$	
Fifth.....	10′ 3″		1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{3}{4}''$	
Fourth...	10′ 3″		2 Pls. $18\times\frac{5}{8}''$ $1-12\times1''$ 4 Zs. $6\times\frac{7}{8}''$	4 Zs. $6\times\frac{13}{16}''$	
Third....	10′ 3″		1 Pl. $12\times1''$ 2 Pls. $18\times\frac{7}{8}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{3}{8}''$	
Second...	10′ 3″		1 Pl. $14\times1''$ 2 Pls. $20\times\frac{15}{16}''$ 4 Zs. $6\times\frac{7}{8}''$	1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{5}{8}''$ 4 Zs. $6\times\frac{13}{16}''$	
First.....	12′ 0″		2 Pls. $20\times1\frac{3}{16}''$ $1-14\times1''$ 4 Zs. $6\times\frac{7}{8}''$	2 Pls. $14\times\frac{7}{16}''$ $1-8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$	
Cellar....	12′ 6″		2 Pls. $20\times1\frac{3}{8}''$ $1-14\times1''$ 4 Zs. $6\times\frac{7}{8}$	2 Pls. $14\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$ $1-18\times\frac{13}{16}''$	

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 53	Col. No. 54	Col. No. 55	Col. No. 56
Twelfth..	....	4 Ls. 2½×2×¼″ 1 Pl. 6×¼″	4 Ls. 2½×2×¼″ 1 Pl. 6½×⅜″		4 Ls. 2½×2×¼″ 1 Pl. 6×¼″
Eleventh.	10′ 3″	4 Zs. 3×¼″ 1 Pl. 6×¼″	4 Zs. 4×⅜″		4 Zs. 3×¼″ 1 Pl. 6×¼″
Tenth....	10′ 3″	4 Zs. 6×⅜″	1 Pl. 6½×⅜″		4 Zs. 5×5/16″
Ninth....	10′ 3″	1 Pl. 8×⅜″	4 Zs. 6×9/16″		1 Pl. 7×5/16″
Eighth...	10′ 3″	4 Zs. 6×⅝″	1 Pl. 8×9/16″		4 Zs. 5×½″
Seventh..	10′ 3″	1 Pl. 8×⅝″	4 Zs. 6×13/16″	Same as Col. No. 47.	1 Pl. 7×½″
Sixth....	10′ 3″	4 Zs. 6×⅞″	1 Pl. 8×13/16″		4 Zs. 5×11/16″
Fifth.....	10′ 3″	1 Pl. 8×⅞″	2 Pls. 14×⅜″ 1−8×¾″ 4 Zs. 6×¾″		1 Pl. 7×11/16″
Fourth...	10′ 3″	2 Pls. 14×5/16″ 1−8×⅞″ 4 Zs. 6×⅞″	1 Pl. 8×¾″ 2 Pls. 14×⅝″ 4 Zs. 6×⅞″		4 Zs. 6×¾″
Third....	10′ 3″	1 Pl. 8×⅞″ 2 Pls. 14×⅜″ 4 Zs. 6×⅞″	2 Pls, 14×⅝″ 1−8×⅞″ 4 Zs. 6×⅞″		1 Pl. 8×¾″
Second...	10′ 3″	2 Pls. 14×3/16″ 1−8×⅞″ 4 Zs. 6″×⅞	1 Pl. 8×⅞″ 2 Pls. 14×⅞″ 4 Zs. 6×⅞″		2 Pls. 14×5/16″ 1−8×¾ 4 Zs. 6×¾″
First.....	12′ 0″	1 Pl. 8×⅞″ 2 Pls. 14×13/16″ 4 Zs. 6×⅞″	2 Pls. 18×⅝″ 1−12×1″ 4 Zs. 6×⅞″		1 Pl. 8×¾″ 2 Pls. 14×⅜″ 4 Zs. 6×¾″
Cellar....	12′ 6″	4 Zs. 6×⅞″ 1 Pl. 10×1″ 2 Pls. 16×13/16″	1 Pl. 12×1″ 2 Pls. 18×15/16″ 4 Zs. 6×⅞″		1 Pl. 6×¾″ 2 Pls. 14×9/16″ 4 Zs. 6×¾

SCHEDULE OF COLUMNS—*Continued*

Floor	Height between floors	Col. No. 57	Col. No. 58	Col. No. 59	
Twelfth..	....	4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		4 Ls. $2\frac{1}{2}\times2\times\frac{1}{4}''$ 1 Pl. $7\times\frac{3}{8}''$	
Eleventh	10′ 3″	4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$		4 Zs. $5\times\frac{3}{8}''$	
Tenth....	10′ 3″	4 Zs. $5\times\frac{3}{8}''$		1 Pl. $7\times\frac{3}{8}''$	
Ninth....	10′ 3″	1 Pl. $7\times\frac{3}{8}''$		4 Zs. $6\times\frac{5}{8}''$	
Eighth...	10′ 3″	4 Zs. $6\times\frac{9}{16}''$		1 Pl. $8\times\frac{5}{8}''$	
Seventh..	10′ 3″	1 Pl. $8\times\frac{9}{16}''$		4 Zs. $6\times\frac{7}{8}''$	
Sixth....	10′ 3″	4 Zs. $6\times\frac{3}{4}''$	Same as Col. No. 45.	1 Pl. $8\times\frac{7}{8}''$	
Fifth.....	10′ 3″	1 Pl. $8\times\frac{3}{4}''$		2 Pls. $14\times\frac{7}{16}''$ $1-8\times\frac{13}{16}''$ 4 Zs. $6\times\frac{13}{16}''$	
Fourth...	10′ 3″	4 Zs. $6\times\frac{7}{8}''$		1 Pl. $8\times\frac{13}{16}''$ 2 Pls. $14\times\frac{9}{16}''$ 4 Zs. $6\times\frac{13}{16}''$	
Third....	10′ 3″	1 Pl. $8\times\frac{7}{8}''$ 2 Pls. $14\times\frac{5}{16}''$			
Second...	10′ 3″	2 Pls. $14\times\frac{3}{8}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$			
First.....	12′ 0″	2 Pls. $14\times\frac{1}{2}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$			
Cellar....	12′ 6″	2 Pls. $14\times1\frac{1}{16}''$ 4 Zs. $6\times\frac{7}{8}''$ 1 Pl. $8\times\frac{7}{8}''$		4 Zs. $3\times\frac{1}{4}''$ 1 Pl. $6\times\frac{1}{4}''$	

being placed just above one floor and the remaining ones above the floors adjoining.

Framing of Domes.—A dome is sometimes an appropriate

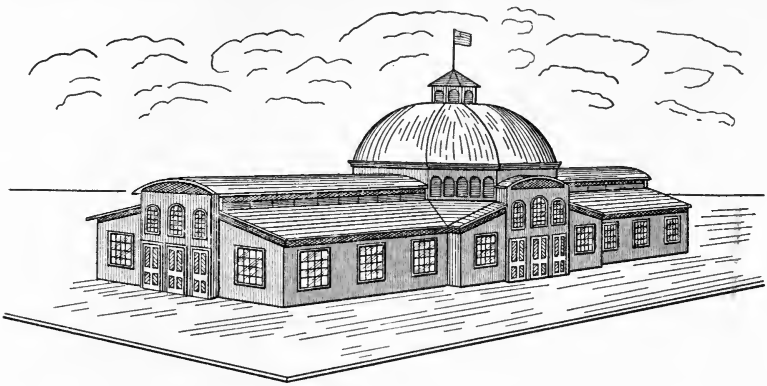


FIG. 50.—Market building with dome.

feature for the office or executive building of an industrial plant, distinguishing it plainly from the surrounding shops, and it is frequently used on markets[1] and exhibition halls. Fig. 50. The

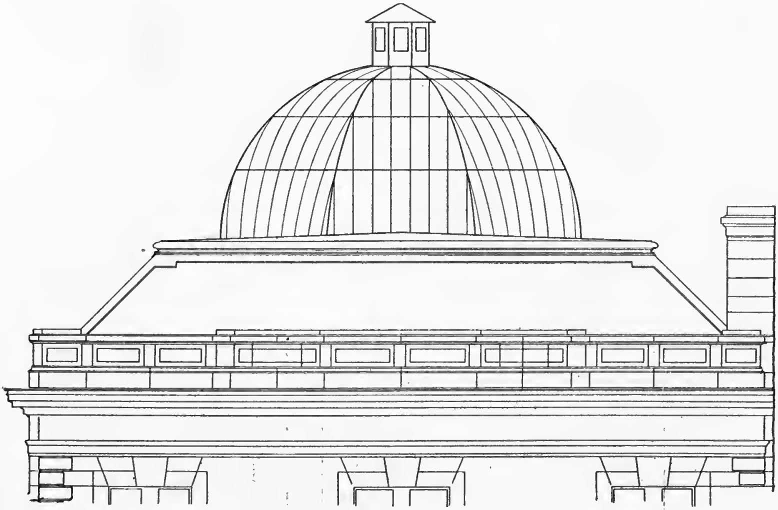


FIG. 51.—Office building with dome.

dome affords not only a beautiful feature in itself by day, but gives opportunity for electric illumination by night, and it can be made an effective means of advertising, as the lights at a con-

[1] H. G. Tyrrell, in *Architect's and Builders' Magazine*, July, 1901.

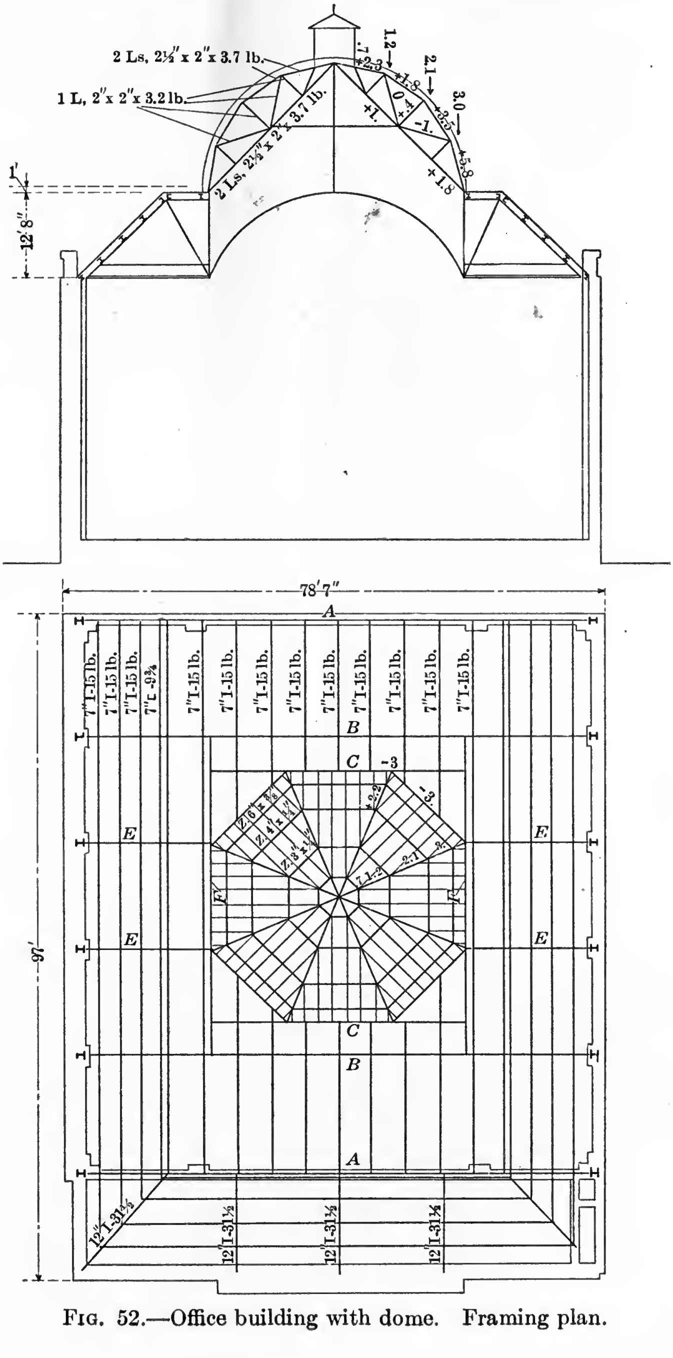


FIG. 52.—Office building with dome. Framing plan.

siderable elevation are conspicuous. No form of roof lends itelf with greater effect to the art of the electrician, for the lines both inside and out are so easily traced with rows of lights that the effect at night is beautiful. No one who has visited any of the recent World's Fairs, and has taken time to study and admire the illumination, can fail to appreciate this form of construction. All the principal lines are indicated with lamps, the numerous ridges radiating from the center to the base—the base itself—and the crown, are all brought out in curves of light. And inside of the building, the effect may be even more attractive. A circle of globes surrounds the inner lining of the dome, and each rib radiating from the center is studded with gems, while at the center is a brilliant cluster.

Since beauty and utility are now so often combined in the design of factory buildings, an illustration is given for the framing of a dome which is suitable for an office, or such other buildings as a library or welfare hall, which are now so often a part of large works.

The roof herewith described (Figs. 51 and 52) is 78 ft. wide, 97 ft. long and the dome is 37 ft. in outside width. It is covered on the outside with curved sheets of rough wire glass supported on copper ribs, and is lined on the inside with another dome of colored glass supported on a light frame suspended from the main ribs.

An unusual feature of the framing is, that no bending is required excepting for the copper skylight ribs. The dome is octagonal in form and each of the trusses is made of straight sections. These trusses carry the purlins, which in turn support the skylight. To resist the bursting effect at the base of the dome, as well as to carry its own weight an arrangement of beams and trusses is provided connecting with the roof principals, and thence to the wall columns. The bursting tendency produces a tension of 3000 lbs. in the members encircling the base of the dome. Each of the main ribs intersects at an angle of the supporting octagon, thus insuring only direct tension in the outside members.

The main roof is covered with slate on 7/8 in. boards laid on tiles between 7-in. steel purlin beams. The ceiling also is made of tile between 6-in. beams, and the whole is furred and plastered on the under side from the wall to the opening of the dome. On all four sides of the main room is a heavy cornice of expanded metal and plaster, and the whole interior, both ceiling and dome, are brilliantly lighted with electric lamps. The coloring of the interior dome produces a beautiful effect by day, and the re-

flection of these colors through the outer dome presents even a more beautiful exterior effect at night.

The weight of steel in the roof and columns, is as follows:

Eight columns	27,600 lb.
Ceiling	17,600 lb.
Trusses and purlins	101,100 lb.
	146,300 lb.

The total cost of the steel work is $4300, which is equal to 55 cents per square foot of ground covered.

Trusses and columns are placed at the rear gable and at the interior partition, with a view to a possible removal of the partition wall, or extension on the rear end. If such changes are not anticipated, two trusses and four columns could be omitted, and the weight of steel reduced to 115,300 lb. and the cost to $3600. This is equal to 14 1/2 lb. or 45 cents per square foot of ground covered.

The tile roof and ceiling is fireproof, but quite heavy and expensive. If it were essential to reduce the cost still further, a cheaper covering such as slate on plank could be used, which would not only cost less in itself, but since it is lighter, would reduce the weight of the steel framing.

If the skylight is not required, the dome might be covered with metal instead of glass, and the interior or lining made of plaster. The domes of monumental buildings are usually gilded on the exterior, which makes them conspicuous during day-light, but if this expense is not desired, they may be covered with plain bright metal which is easily seen at a great distance. In either case, electric illumination may be used at night. Ventilation must be provided, especially with glass covering; otherwise the excessive summer heat is liable to crack or melt the glass. An ornamental ventilator is shown on the drawing, but if preferred, the dome may be finished with a simple crown, and ventilation provided through port holes in the side or louvres around the base.

The cost of the roof with dome is about $700 more than if roofed directly over, and an equal amount of light admitted through several box skylights.[1]

Long Span Roofs.—Although long roof spans without intermediate columns are not often used for shops and factories, they are frequently convenient for such buildings as rolling mills,

[1] H. G. Tyrrell, in *Architects' and Builders' Magazine*, March, 1905.

and are usually preferred for drill halls, armories, exhibition halls, train sheds, etc., (Fig. 53). As the floor is then free from columns, tracks or machinery can be placed anywhere without restriction. Wide spans are, however, not economical when hoisting appliances are suspended from the framing, for the weight and cost of trusses increases rapidly with the span and supported load.

For the purpose of estimating approximately the weight and cost of long span roofs, without inside columns, the following data will be useful. The weights are for the steel only, including trusses, shoes, bracing and purlins, but they do not include wooden jack rafters, boards or covering, nor any gallery framing. Weights given are per square foot of sloping roof surface. Arched

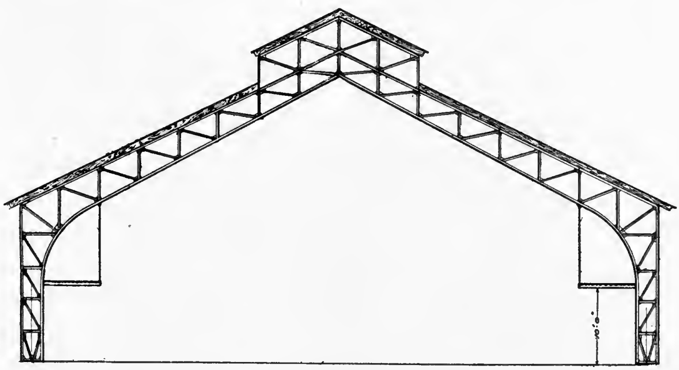


FIG. 53.—Roof without interior columns.

roofs, not including the items mentioned above, usually weigh from 8 to 12 lb. per square foot of outside area. All of the following cases were proportioned for slate and plank roofing on wood rafters 2 ft. apart, supported by steel purlins at intervals of about 10 ft. The unit stresses were 12,000 and 15,000 lb. per square inch in compression and tension respectively. They all have curved arch ribs and are similar in general outline. The spans are the distances between centers of side bearings, which are 4 to 5 ft. less than the outside width of the building.[1]

The assumed loads on these roofs are as follows:

Dead weight of roof and covering, for trusses, 25 lb. per square foot of sloping surface, and for purlins, 18 lb. per square foot.

[1] H. G. Tyrrell, in *Architect's and Builders' Magazine*, Oct., 1901.

Dead weight of snow, 10 lb. per square foot of sloping surface
Wind pressure was assumed at 40 lb. per square foot horizontal or 28 lb. normal to the surface.

Pawtucket armory is 82 ft. wide and 143 ft. long, with five main trusses, 24 ft. apart. The roof pitch is 33 degrees, and the heights are, 16 ft. to eave, and 40 ft. to ridge.

QUANTITIES

5 trusses	67,000 lb.
42 purlins	28,000 lb.
12 purlins	7,500 lb.
bracing	6,100 lb.
5 ties	2,900 lb.
10 shoes	4,500 lb.
Total	116,000 lb.

This weight is equivalent to 8.7 lb. per square foot of sloping roof surface.

Portland armory has a span of 92 ft., and length of 153 ft., with five main trusses 25 ft. apart. Its height to eaves is 24 ft., and to the ridge 50 ft.

QUANTITIES

3 trusses at 17,860 lb	53,580 lb.
2 trusses at 19,700 lb	39,400 lb.
6 cast shoes	2,100 lb.
4 cast shoes	1,400 lb.
3 tie rods	2,457 lb.
2 tie rods	1,980 lb.
28 purlins	19,100 lb.
8 purlins	9,600 lb.
18 purlins	22,400 lb.
8 purlins	5,184 lb.
4 purlins	2,876 lb.
44 bracing struts	4,488 lb.
36 bracing struts	3,300 lb.
72 rods	3,540 lb.
Total	171,400 lb.

This weight corresponds to 9.7 lb. per square foot of sloping roof surface, or 11.7 lb. per square foot of ground covered. The trusses in this case were made strong enough to carry a 13-ft. gallery on two sides and one end, to be added in the future.

Phoenix Hall (Fig. 54), Brockton, Mass. is 100 ft. wide, and

144 ft. long outside. It has five main arches 94 ft. center to center. Distance between trusses is 24 ft. It is 33 ft. high to eaves, and 67 ft. to the ridge, and has a gallery 17 ft. wide. The only steel included for the gallery is that for the ten brackets.

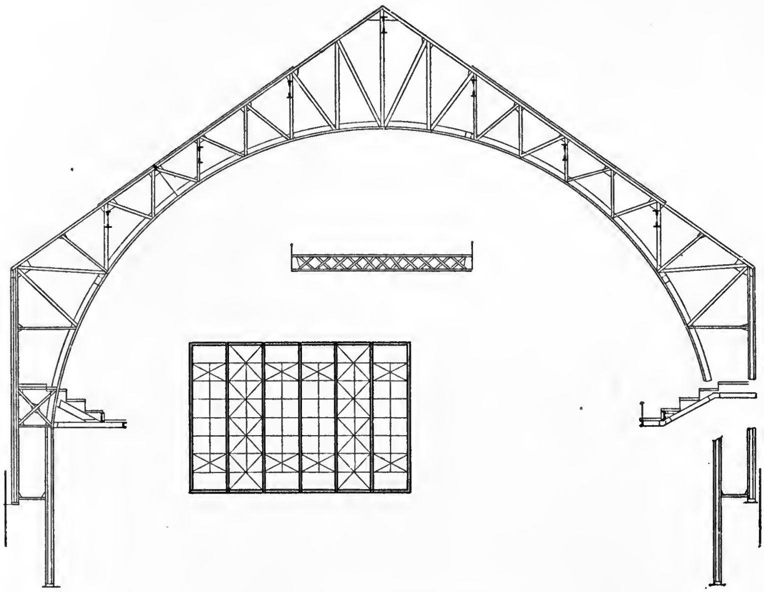


FIG. 54.—Three-hinged arch roof.

QUANTITIES

42 purlins	28,700 lb.
48 struts	6,600 lb.
rod bracing	2,600 lb.
5 tie rods	4,680 lb.
5 arches	99,500 lb.
10 shoes	3,100 lb.
10 gallery brackets	6,060 lb.
Total	151,240 lb.

This weight is equal to 8.6 lb. per square foot of sloping roof surface, or 10.6 lb. per square foot of ground covered.

Northampton Armory, is 100 ft. wide and long, or square in plan. It has three main trusses, and eleven lines of trussed purlins, and no gallery.

QUANTITIES

3 trusses at 17,000 lb	51,000 lb.
6 cast shoes at 350 lb	2,100 lb.
3 tie rods at 780 lb	2,340 lb.
44 purlins at 670 lb	29,500 lb.
bottom chord struts	5,200 lb.
bottom chord ties	2,100 lb.
Total	92,240 lb.

As the sloping roof area is 11,600 sq. ft. the weight per square foot is 7.95 lb.

Hartford Rink is 104 ft. wide, and 124 ft. long. It has four main ribs 54 ft. high center to center of pins, is 24 ft. high to eaves, and has a gallery 16 ft. above the floor, which in this case is framed of steel, the main brackets being framed with the trusses. The roof has seven lines of trussed purlins.

QUANTITIES

Trusses and rafters	132,400 lb.
Purlins	34,400 lb.
Rods	18,000 lb.
Total	184,800 lb.
Gallery	67,600 lb.

The total exposed roof area is 15,600 sq. ft., and the weight per square foot is therefore:

Roof	$184{,}800 \div 15{,}600 = 11.8$ lb.
Gallery	$67{,}000 \div 15{,}600 = 4.4$ lb.

Providence Exposition Hall.—This is 118 ft. wide, and 196 ft. long, and has seven main trusses, 20 ft. high to eaves.

QUANTITIES

7 trusses at 25,000 lb	175,000 lb.
105 purlins at 580 lb	60,300 lb.
7 tie rods at 1,100 lb	7,700 lb.
Rafter bracing	4,000 lb.
96 struts at 100 lb	9,600 lb.
14 cast shoes at 600 lb	8,400 lb.
Total	265,000 lb.

This weight corresponds with 9.5 lb. per square foot sloping, or 11.5 lb. per square foot horizontal.

The following table gives a summary of weights and data for the roofs described above.

TABLE OF LONG SPAN ROOFS

	Span ft.	Length ft.	Truss spacing ft.	Height to eave, ft.	Gallery	Weight per square foot, sloping, lb.	Weight per square foot horizontal, lb.	One truss, lb.
Pawtucket....	82	143	24	16	None	8.7	10	13,400
Portland......	92	153	25	24	....	9.7	11.7	18,000
Phoenix......	96	144	24	33	....	8.6	10.6	20,000
Northampton..	100	100	24	....	None	8.0	9.2	17,000
Palace........	104	124	25	24	....	11.8	14.7	23,000
Providence....	118	196	24.5	20	None	9.5	11.5	25,000
Cleveland.....	120	....	23	....	....	....	....	....
Boston.......	122	300	30	16.5	None	12.4	16.2	42,000
New York....	176	225	24.5	....	....	....	....	....
Brooklyn.....	196	300	35	32	....	....	10	....

All of the above examples have arch action, a graphical analysis of stresses for a typical case being shown in Fig. 55. A simple truss roof with curved lower chord but without any arch action is illustrated in Fig. 56.

For the purpose of comparison, the following table is given of long roof spans for train sheds:

TRAIN SHED ROOFS

Place	Railroad Co.	Span ft.	Length ft.	Rise ft.	Number of Tracks	Area Covered sq. ft.
Jersey City........	C. R. of N. J.......	142	512	......	12	....
New York.........	Grand Central... ..	199	652	94	....	129,800
Chicago...........	C. R. I. & P.........	207	578	......	11	....
London...........	Midland............	240	706	107	....	169,400
Jersey City........	P. R. R.............	252	653	90	12	164,900
Pittsburg..........	P. R. R.............	255	555	......	12	....
Philadelphia........	P. & R.............	259	506	88	13	131,200
Philadelphia........	P. R. R.............	300	598	108	16	177,100

Cost of Steel Frame Buildings.—One-story steel mill buildings erected complete, with solid walls and crane supports, cost 80 cents to $1.10 per square foot of ground covered, not including ground floors or foundations, and similar buildings with crane supports and corrugated iron walls will cost from 70 cents to $1 per square foot. One-story steel frame sheds or buildings (Fig. 57) without provision for cranes, and with corrugated iron covering, will cost, erected complete, from 50 to 70 cents per square foot of ground covered.

The cost of materials, at the place of manufac-

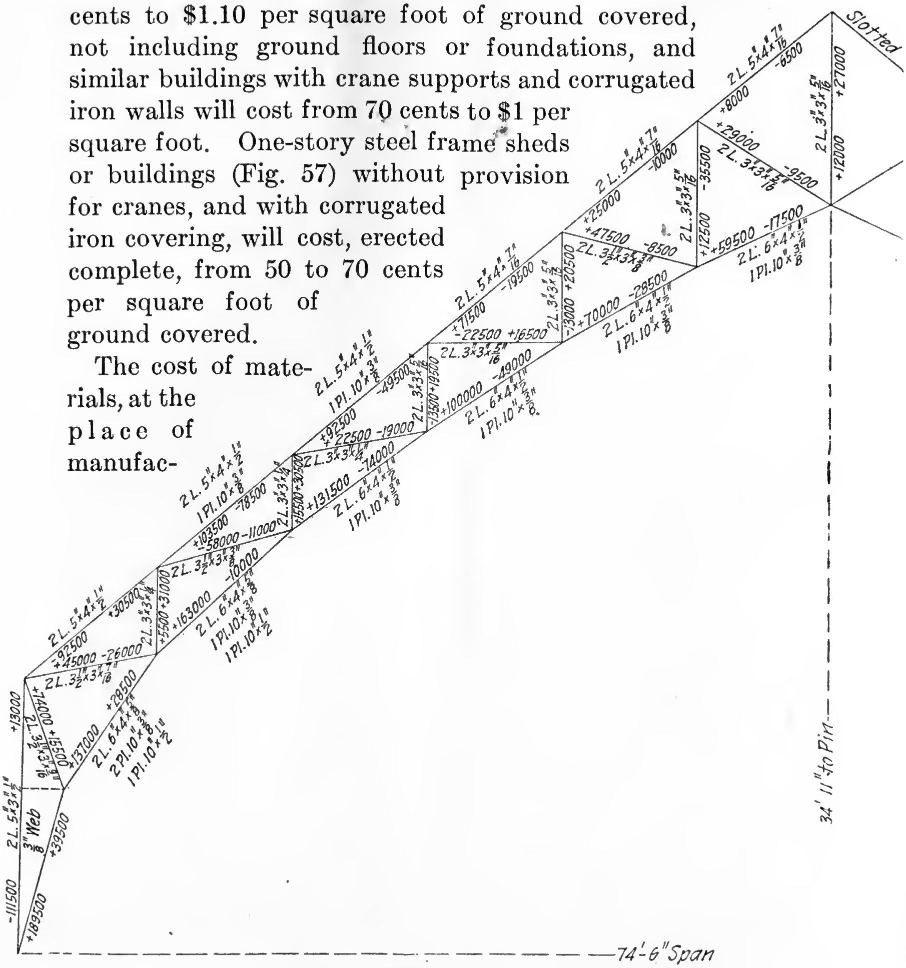


FIG. 55.—Three-hinged arch roof. Stress sheet.

ture but not erected, for steel frame buildings with sheet metal covering, including structural steel, corrugated iron, doors, windows, flashings, gutters, conductors, but without ground floor or foundations, is as follows: Machine shops and foundries, 40 to 50 cents per square foot of ground covered; sheds, enclosed on roof and sides, 30 to 40 cents per square foot of ground covered.

The cost of corrugated iron buildings (Fig. 58) without cranes may also be approximated by finding the total exposed outside

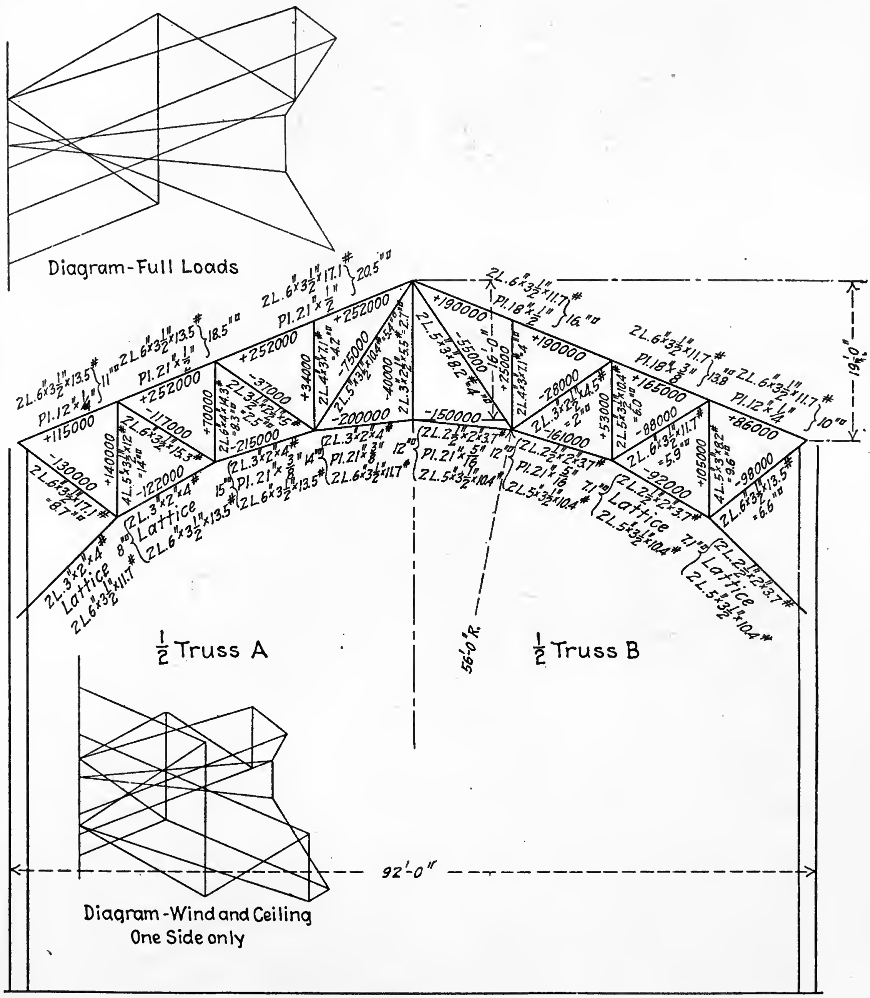


FIG. 56.—Sample roof truss with curved bottom chord. Stress sheet.

area of the building, including both walls and roof, and multiplying it by 30 cents per square foot. Steel frames for cranes

including supports and girders only, cost from 70 cents to $1 per lineal foot of building for every ton capacity of the crane.

The weight of steel frames in multi-story factory buildings

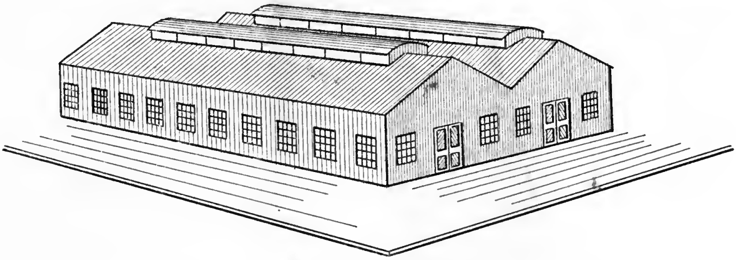


Fig. 57.—Metal covered boiler house.

not over eleven stories in height, with steel joist, girders and columns, designed according to modern specifications and building laws, with columns 15 to 16 ft. apart are as follows:

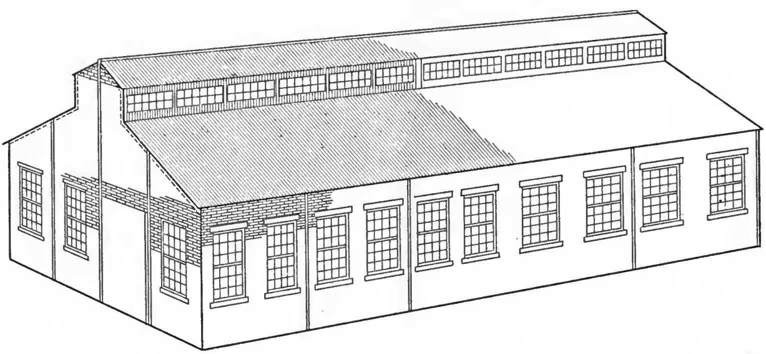


Fig. 58.—A power house.

TABLE V.—WEIGHT OF STEEL FRAMES IN MULTI-STORY BUILDINGS [1]

Imposed floor load, pounds per squar efoot	Exterior walls	Weight of steel, pounds per square foot of floor
60	With outside frame.	14
60	Without outside frame.	9
100	With outside frame.	23
100	Without outside frame.	15
250–300	With outside frame.	28
250–300	Without outside frame.	18

[1] H. G. Tyrrell, in *Architects' and Builders' Magazine*, Jan., 1903.

The approximate cost of the steel frame for a building of several stories can readily be obtained by multiplying any of the above weights per square foot, by the total floor area and the cost of steel per pound, which is usually from 2½ to 3½ cents erected.

Fireproof steel buildings in cities, with terra cotta floor arches, cost, when complete, 20 to 25 cents per cubic foot.

Fireproof steel buildings in cities, with concrete floors, cost from 15 to 18 cents per cubic foot.

The finished cost of those with terra cotta floors is usually from $2 to $3 per square foot of floor.

Estimates on building work for export to other countries are usually made for the materials delivered on the wharf at some seacoast city, from which ships sail for the foreign port. These estimates include American prices only, and foreign ones need be considered only when the American firm intends to complete the building in the foreign country.

CHAPTER VIII

CONCRETE FRAMING

It is well known that concrete was extensively used by the Romans 2000 years ago or more, as the dome of the Pantheon and many other Roman buildings are of this material. Concrete reinforced with metal was more or less used through succeeding ages, for walls of this material faced with stone, were lately discovered when putting in new lifts in the Louvre at Paris, which was built by order of Francis I in the sixteenth century. The material itself is therefore very old, the only new feature being its commercial use and application.

The modern high-grade product known as Portland cement was discovered by Joseph Aspdin of Leeds, England in 1824, and it is to the recent development of methods for producing it in large quantities at low cost, that much of the recent progress is due. The first reinforced concrete building in the United States was a residence at Port Chester, N. Y. erected in 1875, and three years later the first really important American patent in this material was issued to Thaddeus Hyatt, though other ones of less practical value had been granted as early as 1844. The first reinforced concrete factory in America was erected in 1887–1888 by Mr. Ernest L. Ransome, but the type seems to have met with no great favor, as the second one of the kind was not undertaken for another ten years, when Mr. Ransome erected one for The Pacific Coast Borax Company at Bayonne, N. J. The early efforts of this American pioneer in concrete building seem to have been discouraging, for the new system received no general recognition until about 1902 when several buildings of the type appeared. During the next five years about forty shops and factories in reinforced concrete were built in America, and since that time the number is too great to enumerate. Progress is well illustrated by a table showing the amount of cement produced.

TABLE VI.—CEMENT PRODUCTION OF THE UNITED STATES (IN BARRELS).

	Portland	Natural
1890	300,000	....
1896	1,000,000	....
1899	5,652,000	9,868,000
1900	8,500,000	....
1901	12,711,000	7,085,000
1903	22,325,000	7,030,000
1905	35,247,000	4,473,000
1906	46,400,000	....
1907	48,785,000	2,887,000
1909	64,991,000	1,538,000
1910	76,550,000	1,139,000

The 1910 production of 76,550,000 barrels of Portland cement had a weight of 13,000,000 tons, and at $5.25 per ton, was valued at $68,205,000. This yearly product was 18 per cent. greater than during the preceding year, the average cost in the United States being 89 cents per barrel. The whole world production of Portland cement in 1910 was 130,000,000 barrels, or less than twice as much as that of the United States. It appears from the above table that, as the production of Portland cement has steadily increased, the use of natural cement has decreased. There seems to have been a decrease also in structural steel, for while the production of one European country in 1906 was 1,200,000 tons, it decreased in 1908 and 1909 to 830,000 and 1,045,000 tons respectively.

Advantages of Concrete Construction.—Plain concrete without reinforcing is strong in compression and is therefore well suited for heavy structures with only compressive stress, such as walls, piers, abutments, foundations, short columns etc., as ordinary mixtures of concrete are at least three times as strong as the best quality of brick work.

Some of the advantages of reinforced concrete buildings are as follows:

1. They are monolithic, with the solidity of stone, and grow harder with age. Floors may after a few years sustain loads 50 to 100 per cent. greater than those for which they were originally designed, or additional stories can be added without strengthening the original frame.

2. They are fireproof and when supplied with wire-glass windows and safety doors, fire can be confined to one story. They are well suited for forge shops or wherever open fires are maintained.

3. Floors can be made waterproof, and during a fire, water will not run through and injure goods in lower stories. For this reason all openings at the floor should have a 3-in. curb.

4. Concrete buildings are durable.

5. They are also sanitary and can be washed out with a hose, being well suited for food factories or packing houses.

6. They are economical in cost. As they often need no sprinkler system they may have a less total cost than wood. Construction expense is reduced, owing to the possibility of using common labor.

7. Local labor and materials can generally be used with much saving of time, for no delay is caused in waiting for structural timber or steel from a distance.

8. They can be easily and quickly erected.

9. The design can be modified at any time, previous to or even during erection, without causing expensive delay.

10. The thinner walls leave a greater area of renting space and produce less load on the foundations.

11. Vibrations are less than in either wood or steel buildings.

12. Machines can run at higher speeds and shafting has less friction and therefore needs less power. Wear on the bearings is also less.

13. Concrete buildings make a larger amount of wall area available for windows.

14. Concrete floors are not affected by mineral or vegetable oils.

15. They are vermin proof, for rats, mice and insects can find no hiding places in the framing as in timber.

16. They have a low heating cost and an even temperature, being warmer in winter and cooler in summer.

Disadvantages of Concrete Construction.—In some respects concrete buildings are not desirable, some of their disadvantages being as follows:

1. Changes or alterations are difficult to make after completion. Therefore, since concrete is hard to tear down, brick walls should be used where extensions are anticipated.

2. When outgrown, they have little or no salvage value.

3. Thin walls and floors easily transmit sound, and in certain places these must be double, with an air space between them.

4. The merit of low cost may in some cases be lost, where instead of common labor the regulations of trade unions may require the employment of bricklayers or men at equally high wages for mixing and placing the concrete, though such men may reasonably be engaged for laying concrete blocks.

5. Shafting and machinery are not so easily attached to the ceiling and floors as in wooden buildings.

6. Buildings with concrete exterior walls usually have an unfinished appearance, unless extra expense is incurred in special treatment of the surface, or unless it is veneered with some other material such as brick.

7. Holes or openings through the walls and floors for the accommodation of pipes or shafting are not easily made after completion, though the cutting of such holes may be no more difficult than through floors of brick or terra cotta.

8. When made of a poor quality of concrete or a dry mixture, the walls may occasionally be found damp inside, though this condition may disappear after three to six months when they become well dried.

9. The effect of certain destructive agencies on reinforced concrete has not yet been positively determined. Sea water containing salt was believed to have a disintegrating effect, but experience so far shows that this is insignificant (*Cement Age*, Oct. 1911). The effect of electrolysis on concrete is not well known though it may have no effect whatever. Water containing acid in solution may have some injurious effect, though it is probably very small. Petroleum and engine oil produce little or no effect on concrete, but those containing fatty acids appear to be injurious.

10. The framing members have a large size. Columns of equal strength in different materials have sizes about as follows:

Riveted steel	8× 8 in.
Cast iron	9 in. round.
Yellow pine	12×12 in.
Spruce	14×14 in.
Concrete	18×18 in.

Beams and girders in reinforced concrete are proportionately large when compared to those of other material. The objection to this is that the large columns occupy a greater amount of floor space, leaving a smaller renting area. This may be important

in large cities such as Brooklyn, where rented space for manufacturing purposes costs 25 to 30 cents per square foot of floor area, or in New York City, where it rents for 40 to 60 cents per square foot.

Materials and Mixing.—The three kinds of modern cement are known as Natural, Portland and Puzzolan or Slag cement. Natural cement is suitable for masonry with only compressive stress, Portland being used for nearly all other cases. Puzzolan cannot be put in any important work.

Aggregates may be either fine or coarse. Fine aggregate contains sand, gravel, or crushed stone, all of which will pass through a screen with 1/4-in. openings. Mortar composed of three parts of fine aggregate and one part of Portland cement should be at least 70 per cent. as strong as that made from one part of cement and three of clean sand. Coarse aggregates should preferably contain stone of assorted sizes, the largest

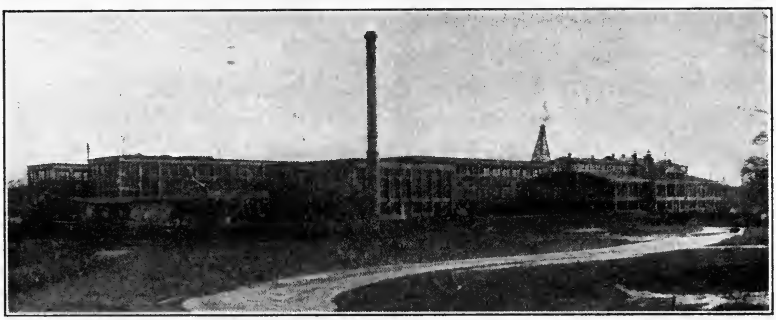


Fig. 59.—Plant of the United Shoe Machinery Co., Beverly, Mass. (F. M. Andrews & Co., architects.)

not exceeding $2\frac{1}{2}$ in. in diameter. Natural gravel and sand has been much used, as in the original building for the United Shoe Machinery shops at Beverly, Mass. (Fig. 59) though on the addition of 1907, crushed stone from a near-by ledge was used instead. A good proportion for concrete in floors and walls is one part of Portland cement with six parts of mixed aggregates, though a richer mixture of one part of cement with four or five of aggregate is better in columns, while a poorer mixture of one to nine or twelve parts of aggregate is enough in foundations. Cinder concrete is good only for fireproofing, but not for any important structural parts.

Cement is supplied either in bags or barrels, the latter being most suitable when dampness is present, or for long ocean shipments. Bags of cement weigh 95 lb. and contain about 1 cu. ft. as ordinarily packed. A barrel of Portland cement contains four bags or 380 lb., and as the empty barrel weighs about 20 lb., the total weight of barrel and cement is 400 lb. The volume of cement depends to some extent on the amount to which it is compressed, and barrels may be made to contain anywhere from 3½ to 4½ cu. ft., though 3.8 cu. ft. weighing 95 lb. each, is the standard.

Natural cement is also sold in bags of 95 lb., though there are only three bags of this to the barrel, which weigh altogether about 300 lb.

Rods or bars should be medium steel with elastic limit not exceeding 32,000 lb. per square inch, though wire mesh is convenient for slabs, and for reinforcing structural parts. As the metal in concrete is preserved only when all water and moisture are excluded, the concrete should be dense enough to perform such duty. When thoroughly enclosed and protected, the metal is safe even under salt or fresh water, as is fairly well proven by the experiments at Boston and Charlestown (*Cement Age*, October 1911). For this reason cracks should be avoided, as steel would soon be destroyed by corrosion when water enters. Experiments to ascertain the effect of paint on metal for reinforcing concrete, show that the adhesion of concrete to steel is decreased 90 per cent. when metal is painted with red lead, and 80 per cent. when coated with oil. It shows also that adhesion is increased from 30 to 40 per cent. when the metal is given a coat of cement grout, mixed thin enough so one pound of cement will cover when applied with a brush, 60 to 70 sq. ft. The cost of cement coating per square (100 sq. ft.) is 15 cents for one coat and 22 cents for two coats, the latter being equal to 60 cents per ton of ordinary metal, or about 1 per cent. of the cost of the steel in place.

The barrel is the most convenient unit of measurement when mixing concrete, and 1 cu. yd., or 27 cu. ft. contain just seven barrels. A mixture which is suitable for foundations, contains:

7 barrels of broken stone, gravel, etc., per cubic yard
3 barrels of sand, per cubic yard
1½ barrels of cement, per cubic yard
25 gallons of water, per cubic yard

The cost of such concrete will frequently not exceed $5 per cubic yard, while a corresponding foundation of quarry or river stone in random sizes laid in cement, might cost $8 per yard, though these prices will depend on local conditions.

The strength of concrete of different ages should be about as follows:

1 month, crushing strength, 4 tons per square foot
3 months, crushing strength, 10 tons per square foot
6 months, crushing strength, 16 tons per square foot
9 months, crushing strength, 21 tons per square foot
12 months, crushing strength, 25 tons per square foot

Design.—The four types of construction commonly used for concrete buildings are:

1. Reinforced concrete interior frame and floors, with brick outside walls.
2. Reinforced concrete interior frame and floors, with concrete walls.
3. Reinforced concrete interior and exterior frame and floors, with curtain-walls.
4. Light self-supporting steel frame, reinforced with concrete.

Number 1 generally has the best appearance and is well suited to small buildings. Number 2, with concrete outside walls is difficult to make attractive in appearance, and is not usually built as rapidly as number 1, besides costing somewhat more, though it is, no doubt, more rigid than either 1 or 3. Number 3 is the most economical design, is quickly erected and can be made attractive by using an exterior curtain wall, with brick veneer over the structural parts. Number 4 is one of the most convenient types of reinforced concrete, and might better be called reinforced steel construction, for the preliminary light steel frame is strengthened with concrete after erection (Fig. 60). Concrete is used for foundations, columns, sills, lintels, beams and floors, and steel for trusses and heavy girders subject to jars or impact. Concrete trusses are not economical, as the forms are expensive, and they are not reliable, as the joints are difficult to make. The light frames of structural steel should be heavy enough to carry the erection loads and form a support for a working platform.

The same amount of care should be exercised in the preparation of designs and plans for concrete buildings as is usually given to structural steel. Stress sheets should show separately all loads, dead, live, impact and wind. Specifications should

give the proportion of materials in different mixtures, and the strength that concrete is assumed to have at the end of a stated period. The ultimate merit of a concrete building will depend largely upon the use of correct designing principles, good details, safe units, careful calculations, proper quality of materials and careful erection. It has long been an axiom of structural design that strength and durability depend on the details, and this is quite as true of concrete framing as of steel. All details should be plainly shown, even minor ones, and sizes, position of rein-

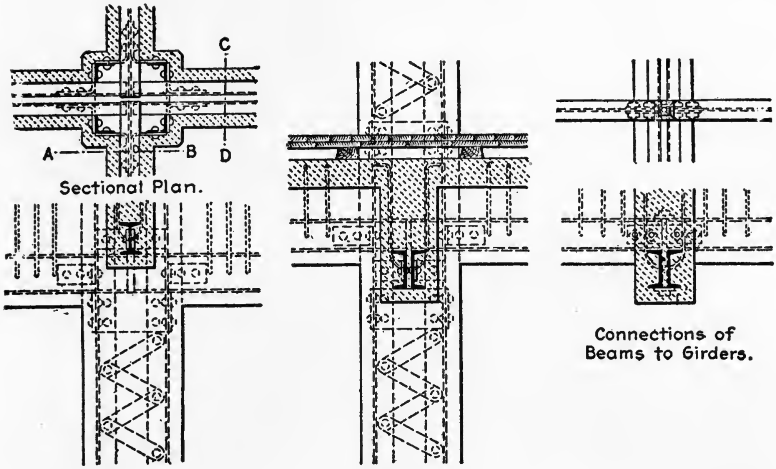


FIG. 60.

forcement, etc., all properly studied out. Special attention should be given to the joints and provision made for temperature changes, shrinkage after placing, and waterproofing. Plans and specifications should be signed in duplicate by engineers or contractors, and these parties should be held responsible for the safety of the building, even though the plans are afterward approved by city authorities or others.

Fine theory is of less importance in concrete construction than in steel, owing to the coarser nature of the materials, and simple formulæ are preferable to complicated ones. As the assumptions on which certain formulæ are based may never be realized within 100 per cent. it is plainly useless to aim at exact proportioning. Attention should be given to essentials, and trifles neglected or lightly treated.

Protection should be made against injury from fire by the burning of a building's contents. Concrete is partly decomposed at a temperature of 900 to 1000° F., but the injured material remains in place and forms a protection for the part beneath it. The new Chicago Building Law gives separate rules for buildings of different heights, those of 90 ft. or more, known as fireproof, may be designated as Class A and lower buildings or non-fireproof ones as Class B.

Class A Buildings

Columns, beams and girders must have not less than 2-in. covering over the metal.

Slabs must have a covering of not less than 1 in. below the metal.

Class B Buildings

Columns, beams and girders must have not less than $1\frac{1}{2}$ in. covering over the metal.

Slabs must have a covering of not less than $\frac{1}{2}$ in. below the metal.

As the effect of fire on concrete has seldom been found to penetrate deeper than $\frac{3}{4}$ in. even in great conflagrations, the provisions given above are large enough, and agree closely with the practice recommended by the Joint Committee on Reinforced Concrete. The additional concrete specified above is for fire protection only, and should not be considered as resisting any direct stresses, though in many cases it actually does add to the strength of the members.

During construction, and after completion the building should be inspected by the engineers or their representatives, and special examination made of the following features:

1. Compare size of members and reinforcing with that shown on drawing.
2. Quality and proportion of materials and methods of mixing them.
3. Nature of forms and hardness of concrete before removing them.
4. Protection against injury after forms are removed.
5. Application of test load on some of the weakest parts, two months after completion.

Working Units.—When proportioning members, working unit stresses should be used as in steel framing, rather than ultimate values, as proposed by some, and these units should be low enough to be well under the danger line.

Stone concrete with an ultimate compressive strength of 2000 lb. per square inch after twenty-eight days, may have the following working units:

Plain concrete in columns, not reinforced..............	Compression, 400 lb. per square inch.
Reinforced concrete.........	Compression, 600 to 750 lb. per square inch.
Compression in outer edge of beams................	Compression, 500 lb. per square inch.

If the compressive unit in columns with vertical reinforcing only, is represented by U, the working stress may be increased by 20 per cent. when hoops only are used, and by 45 per cent. if the column has both vertical reinforcing and spiral winding. Tension in concrete should in most cases be ignored.

Adhesion.—The ultimate adhesion value of concrete to clean steel is 500 to 600 lb. per square inch, but working stresses should not exceed 60 to 80 lb. per square inch for plain bars, and 30 to 50 lb. for wire.

The working shearing stress in concrete that is not reinforced, should not exceed 40 lb. per square inch, though 60 lb. is permissible with partial reinforcing, and 120 lb. per square inch when fully reinforced.

Tensile stress in reinforcing bars should not exceed 14,000 lb. per square inch in soft steel, and 16,000 in medium steel. The permissible compressive strength of cinder concrete at the end of 30 days, does not exceed 700 to 900 lb. per square inch, and its weight is usually about 110 lb. per cubic foot.

Separately Moulded Members.—In this type of construction, the parts are moulded either at the site or in a factory and then shipped to the building, the former method usually being the cheaper. A number of types have been devised including the Siegwart, Vaughan, Armoured Tubular, Climax, Unit, Standard and Watson systems. Some of these relate only to the floors, others only to the frames, while some include both. The Siegwart system of hollow concrete beams (Fig. 61), though originally a European product, is manufactured also at Montreal, Canada, the cost of floor when erected varying from 17 to 26 cents per square foot, depending on the span and load specified.

The Armoured Tubular system (Fig. 62) is an English product costing about 22 cents per square foot. Climax beams (Fig. 63) are made in Chicago, and the Unit, Standard (Fig. 62a), and Watson systems (Fig. 63a) are also American.

Separately moulded members, when factory made, have the

FIG. 61.—Seigwart floor beams Standard Sect. No. 21.

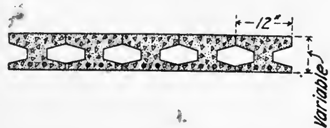


FIG. 61a.—Vaughan system.

advantage that the proportion of materials can be more exact and the members can be tested before erection. They are more reliable, and higher working stresses may therefore be allowed, with a corresponding decrease in materials and weight. They need fewer forms than monolithic work and this item of expense

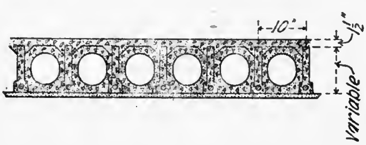


FIG. 62.—Armoured tubular system.

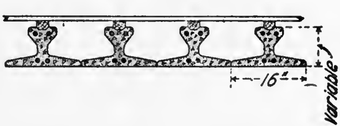


FIG. 62a.—Standard system.

is, therefore, comparatively small. They can be quickly erected and alterations after completion are more easily made with separate members than with solid construction, the former being more like other block structures.

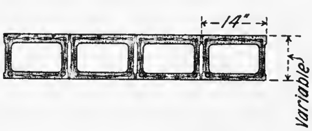


FIG. 63.—Climax system.

FIG. 63a.—Watson system "A."

The disadvantages of buildings made of separately moulded members, are:

1. Lack of rigidity, and (2) increased amount of reinforcing metal. The first of these objections disappears to some extent when the parts are well connected with dowels and cement.

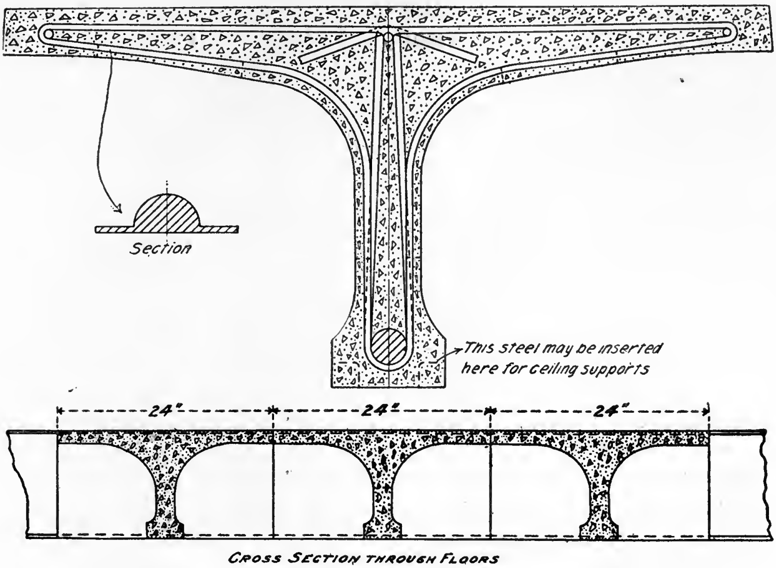


FIG. 64.—Detail of Watson system. Separately moulded beams.

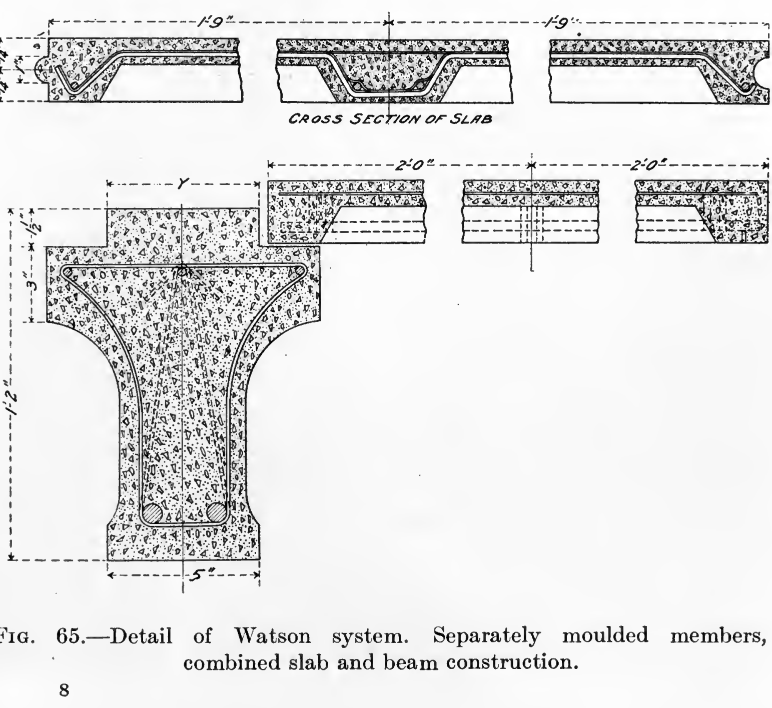


FIG. 65.—Detail of Watson system. Separately moulded members, combined slab and beam construction.

The increased amount of reinforcing metal is due chiefly to a lack of continuity in beams and slabs, and is a condition which is not easily overcome.

The following table gives comparative weights per square foot of floor for all materials, including reinforcing metal, in concrete floors of different types.

	Weight of all materials lbs.	Weight of steel lbs.
Flat slabs	96	3.75
Concrete and tile (Kahn system)	72	2.77
Slab and beam	56	2.41
Terra-cotta arches with concrete top between steel beams.	55	5.4
Watson system	45	2.75

Concrete structural members are conveniently made at the building site by first laying the shop floor, which may then be used as a working platform on which to make the pieces for the superstructure. Slabs may be cast in piles with nothing more than heavy waxed manila paper between them, which is easily removed after erection by a jet of water from a hose. The pieces may be slightly offset in the piles to facilitate handling. When the concrete in the members has hardened, they can be erected with a stiff leg derrick or a traveling crane at a cost for hoisting which should not exceed $1 per ton.

The relative cost of buildings of the monolithic and separately moulded types can best be shown by a comparison of two duplicate ones built for the Central Pennsylvania Traction Company.

It appears, therefore, that the building with separately moulded members cost $2.185 per cubic yard of concrete, less than the monolithic building. To offset this saving, the building with separately moulded members contained 20 per cent. more material than the other, but even so, the net saving in favor of the building with separate members was 15 per cent.

The addition to the United Shoe Machinery Company's building at Beverly, Mass., which has separately moulded framing members cast on the ground, but monolithic floors, showed a saving of 10 per cent. over the original building, which

TABLE VII

Materials and labor	Cost per cubic yard	
	Monolithic	Separately moulded
Materials:		
Stone, sand and cement	$3.480	$3.480
Reinforcement	.915	1.140
Lumber	1.335	.480
Paper	.000	.040
Tools	.145	.145
Total material	$5.875	$5.285
Labor:		
Carpentry work	3.250	.965
Bending and placing	.095	.230
Concreting	2.210	1.685
Erection	.000	1.080
Total labor	$5.555	$3.960
Total material and labor	$11.430	$9.245

was wholly monolithic, both the addition and the original being built under the direction of Mr. Ernest Ransome. The cost of grouting the face after completion was 1 cent per square foot.

Comparative costs are also available for two other buildings of separate members, namely, the Textile Machine Works of Reading, Pa., and the Edison Portland Cement Company's buildings. The plant at Reading cost 80 cents per square foot of floor for the frame and floor only, without curtain walls, finish or engineering charges, and 25 per cent. of this cost was for carpentry labor and forms. The building when completed cost only 7.7 cents per cubic foot. The Edison Portland Cement Company's building is one story high, 144 ft. wide and 360 ft. long, with 32-ft. columns and 24-ft. girders, all made at the building site. The cost of making and erecting the concrete was only $6.60 per cubic yard, which is extremely low, and could hardly be reproduced at less than $7.50 to $8. Cement cost $1 per barrel, and crushed stone 60 cents per cubic yard.

The cost of 4-in. slabs in place, when moulded in a horizontal position previous to erection, is about as follows:

	Cost, cents per 100 sq. ft.	
Steel	2.36	equal to 30 per cent. of total
Concrete labor	2.55	equal to 32 per cent. of total
Carpenter labor	.59	equal to 7.5 per cent. of total
Labor, mixing and placing	.56	equal to 7 per cent. of total
Erection	1.86	equal to 23.5 per cent. of total
	7.91	equal to 100. per cent. of total

Columns.—Three kinds of columns are ordinarily used in concrete buildings.

1. Columns with vertical reinforcing only.
2. Columns with vertical reinforcing and hoops.
3. Columns with light structural steel frames.

Square columns, even in the upper stories, seldom have less than 12-in. sides, and the corners usually have a 1-inch champfer. The general practice is to use square columns with only four vertical reinforcing rods for sizes of 16 to 18 in. In lower stories where greater strength is needed, hoops or spiral winding may be used, in which case an octagonal form with eight rods is preferred. Columns in walls may have a uniform thickness through several stories, increased sectional area being secured by a change in width. A mixture of cement, sand and stone, in the proportions of 1, $1\frac{1}{2}$ and 3, is the best, and stone should generally not exceed 1 in. in diameter. Columns should be reinforced when their length exceeds six times their diameter, and when extra material is added for fireproofing, only the area inside of the fireproofing should be considered as sustaining loads. The maximum column length should never exceed fifteen times the inside diameter. An additional thickness of 1 to 3 in. over the structural part should be allowed for fireproofing as previously described under "Design."

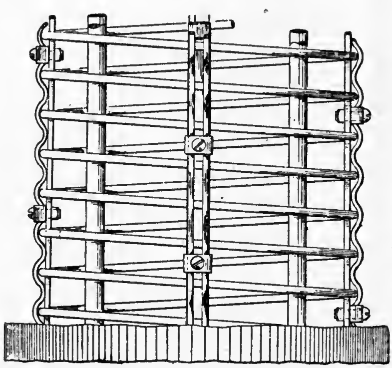


FIG. 66.—Spiral reinforcing for columns.

Vertical reinforcement when used, may vary from 1 to 5 per cent. of the inside column area, the average being about 2 per cent. Four rods are most convenient in square columns, and eight in octagonal ones, and bars are quite as good plain as when roughened. They should be spliced just above the floor level with butt joints, and the bars surrounded with sections of pipe about 12 in. long, and 1/4 in. larger inside than the diameter of the rod. Footing plates should be placed under the rod at the base of the columns, and these plates should be large enough to distribute their portion of the load. Column hooping (Fig. 66) may consist of either bands or spirals, the latter being conveniently made of round bars from 3/16- to 1/2- in. diameter with a pitch of 2 to 4 in., the spacing being maintained by flat bars notched at the proper interval. Bands when used may be spaced from 4 to 20 in. apart, the usual practice being 12 in.

The cost of columns 18 in. square per foot vertical is about as follows:

Concrete	$0.55 per vertical foot
Steel	.75 per vertical foot
Forms	.50 per vertical foot
Total	$1.80 per vertical foot

The most economical column spacing depends upon the loads and the kind of floor construction. For 250 lb. per square foot or less, the economical column spacing for two different floor types is:

Floor with beams and girders	18×18 ft.
Floor with flat slabs	20×20 ft.

For loads of 300 lb. per square foot or more, the column spacing for the above types is:

Floors with beams and girders	15×15 ft.
Floors with flat slabs	17×17 ft.

Beams.—Experiments show that reinforced concrete beams are at least ten to twelve times stronger than beams which are not reinforced. They are generally suitable in building frames, but in some places, such as crane girders, subject to frequent and heavy jars and impact, steel framing is more reliable. And yet reinforced concrete beams have occasionally been used even for crane girders, as illustrated in the shop for the Ingersoll Milling Machine Company at Rockford, Ill.

The cross-sectional outline of concrete beams is usually rectangular, or in the form of a broad T. A good proportion for rectangular beams is to make the depth from one-tenth to one-twelfth of the span length, and the width from one-half to three-fourths of the depth. Deep and narrow beams contain less material and are proportionately cheaper than wide and shallow ones. T-beams are really ribbed or stiffened slabs, the compression being resisted by the slab, and the tension by bars in the lower part of the stem, the concrete stem acting like the compression braces in trussed beams to separate the rods from the compression chord. The proportioning of T-beams is at the best only a rough approximation, for it is impossible to know how great a width of slab is subjected to compression. The common practice is to assume the breadth of T-beams (Fig. 67) as not more than one-fourth of the span, and the distance at each side from the stem to the edge of the compression flange as not more than four times the slab thickness. The width of the stem is frequently assumed at one-third to one-fifth of the slab width. If the stem were wide enough there would be no need of assuming any part of the slab in compression. It is, therefore, inconsistent to attempt fine proportioning in concrete beams of any kind, for the nature of the material and the primary assumptions are such as to make these efforts useless. While the coefficient of elasticity for steel is quite close to 30,000,000, that for reinforced concrete varies anywhere from 1,500,000 to 5,000,000, and their relative proportions or the value usually designated by the letter N, varies accordingly from 6 to 20. Some other assumptions have quite as large a variation. The complicated beam formulæ proposed by some writers, are, therefore, not only absurd, but an actual waste of time, and simple formulæ only are appropriate.

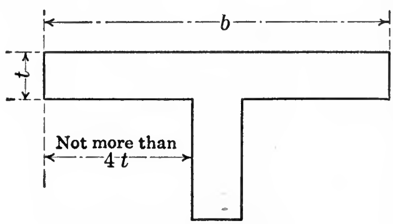


FIG. 67.—T-beam.

Since the compression in slabs and beams is usually resisted wholly by the concrete, joints in these members should be made near the center of the span. In this position cracks are of little consequence, but near the end in the region of maximum shear, they are serious. When a condition of continuity exists, it is

customary to assume the bending moment as 25 per cent. less than for simple beams supported at the ends. The formulæ for continuous beams are

$$M = \frac{WL^2}{12} \text{ for intermediate spans}$$

$$M = \frac{WL^2}{10} \text{ for end spans}$$

where M is the bending moment in foot-pounds

W the load in pounds per lineal foot

L the length of span in feet.

When square panels are reinforced in two directions, one-half of the above stresses should be considered in each system.

Beam and girder reinforcement are less expensive and more effective when made into unit frames (Fig. 68) in a metal shop than when loose bars are assembled in the beams at the building site. Enough reinforcement should be used to prevent

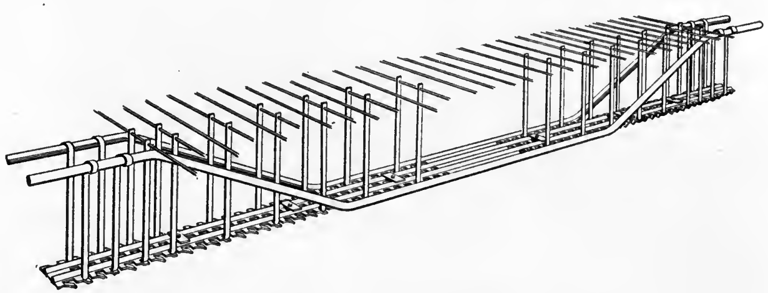


Fig. 68.—Unit girder frame.

deflection, for when this occurs cracks will form, which may admit enough water or moisture to ultimately destroy the bars with rust. Beams may have from two to eight reinforcing rods and rods should not be closer together horizontally than 2½ to 3 diameters and the clear space between two layers of bars should not be less than 1/2 in. The distance from the center of a bar to the bottom or sides of beam should not be less than two diameters of the bar, in order to secure a good bond and to protect the metal from fire. The bond between concrete and steel depends wholly upon the contraction of the concrete when hardening, during which process it forms a grip on any material embedded therein. There is no chemical affinity or

union, for if cement or concrete is placed on a metal surface and allowed to harden, it can very easily be broken off. The concrete must, therefore, surround the metal in order to form a grip. Plain unpainted bars, either round or square, are the best and a slight coat of rust is no disadvantage. Bars should not be spliced at the point of maximum stress, and the length of lap will depend on the amount of stress at the point of splice and the assumed adhesive unit. Sharp bends in shear rods must be avoided, and diagonals should have effective end anchorage.

Stirrups (Fig. 69) have been found to increase the shearing strength of beams by 300 to 400 per cent. Their distance apart longitudinally should generally not exceed three-quarters of

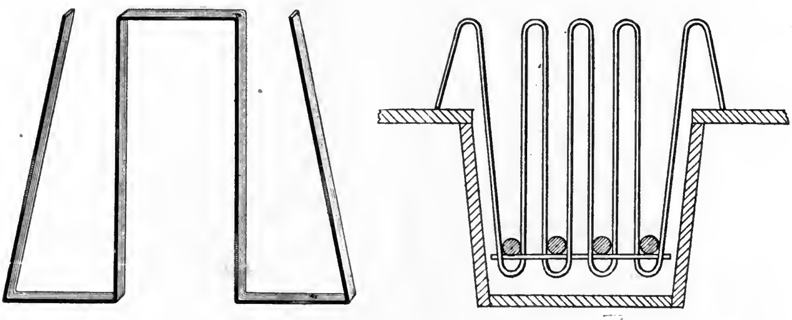


FIG. 69.—Stirrups for reinforced concrete.

the beam depth, and they should be connected to the horizontal rods. A good empirical rule is to use four stirrups at each end of concrete beams, spaced about as follows: Place the first stirrup one-quarter of the beam depth from the end, and the second, third and fourth should follow at distances of one-half, three-fourths, and once the depth of the beam in each case from the preceding ones. A vertical sheet of expanded metal or wire mesh may be used instead of the stirrup bars.

An original formula devised by the writer, for concrete beams, which is easily applied and yet safe, is as follows:

$$D=\sqrt{\frac{M}{CB}}$$

where D = depth of beam in inches, from the upper surface to the center of the rods

M = bending moment in inch pounds
C = a factor varying from 60 to 150, but usually taken at 100.
B = breadth of beam in inches.

The cost per lineal foot of concrete joists, 6×12 in., is about as follows:

Concrete and steel..............	$0.45 per lineal foot.
Forms..........................	.25 per lineal foot.
Total......................	.70 per lineal foot.

The cost per lineal foot for reinforced concrete girders, 12×20 in., is:

Concrete and steel..............	$0.60 per lineal foot.
Forms..........................	.35 per lineal foot.
Total	.95 per lineal foot.

Reports on the cost of concrete of 1-2-4 mixture, in a number of large buildings, showed that for the concrete alone without forms or reinforcing metal, the average cost of concrete in floors was $6.10 per cubic yard, and in the columns, $6.70 per cubic yard, when cement cost $1.35 per barrel, and sand and crushed stone, 80 cents and $1.25 per cubic yard respectively. Plant rental, coal, and power cost from 50 cents to $1.50 per cubic yard of concrete.

The above data is based on Chicago prices in 1911, and should be carefully modified to suit the local price of labor and materials, variations in which may cause great changes from the above approximate costs.

Machinery Connection to Concrete Floors.—Connections to shop floors differ according to the size and weight of the machines. The best practice for heavy machines is to raise them about ½ in. above the floor and to run in thin grout to a width of 4 to 5 in. all around. Light machines with insufficient weight to hold them in place must be fastened to the floor by expansion bolts set in holes 1½ to 3 in. deep, drilled into the slab, a shield being used when drilling, to prevent the tool from going through the floor. In other cases, machines have been bolted through the floor slab and fastened with nuts and washers on the under side. Very light machines may sometimes be screwed down to a temporary wood floor placed over the concrete.

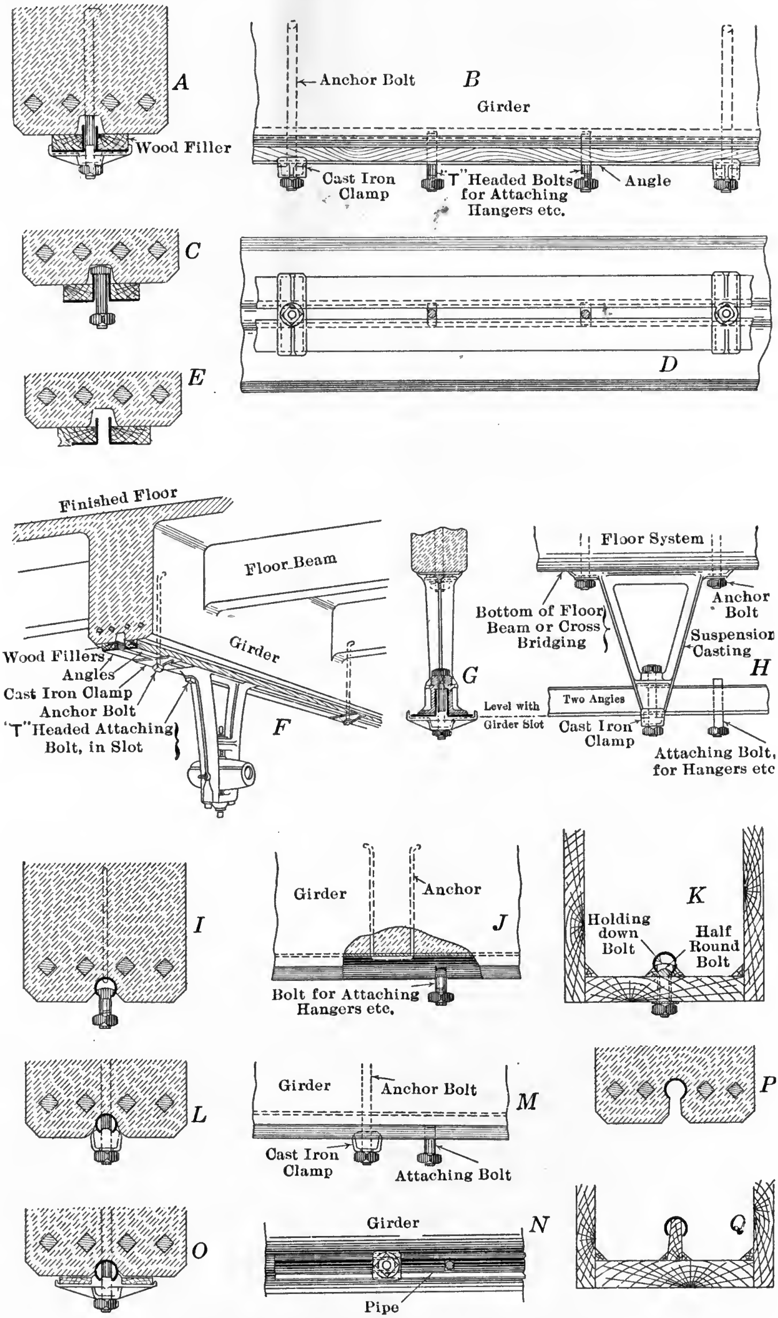


FIG. 70.—Connections to concrete beams.

Shafting Attachment.—There are a number of good methods in use for attaching shafting to the under side of concrete beams and floors (Fig 70) and other details can easily be devised as needed to suit special cases. If no provision was made for such attachments when the building was first erected, holes can then be tapped for expansion bolts, using a portable air drill. This machine works quickly and at very small cost.

When connections are planned beforehand, holes may then be left 2 to 3 ft. apart through the beams beneath the floor, and in flat floors without beams, cast-iron spool sockets can be set into the ceiling. Holes in the walls and floors for plumbing and heating pipes should have cast-iron spools or sockets and they should, if possible, be placed during first construction. For this purpose subcontractors for plumbing and heating should supply the concrete contractor with a plan showing the size and position of all such openings.

Waterproofing.—Concrete made with wet mixture is impervious to water, and walls of this kind with no greater thickness than 8 in. and without any waterproofing may safely be used for cellars and basements. It is only when concrete is made too dry that walls are pervious. Concrete blocks which often have a dry mixture in order to make them quickly are subject to this objection. Condensation is likely to form in basements or other damp places, but this can be avoided by lath and plaster over furring. Where there is danger of crack formation from temperature changes or other causes, metal reinforcement should be used. This will prevent the formation of large cracks and produce a larger number of small ones so narrow that moisture cannot enter.

Waterproofing may be necessary to prevent moisture from soaking into the joints and freezing, thereby tending to disintegrate the masonry. It may be necessary also to prevent water leaking through, and discoloring or otherwise disfiguring the interior of the building. Waterproofing may be affected in several ways.

1. By making a rich and wet outer mixture of mortar with equal parts of Portland cement and sand. On horizontal surfaces this can be laid as granolithic with a troweled surface on a wet or green base, at a cost of about 5 cents per square foot.

2. By covering the outer surface of the concrete with layers of waterproof felt coated with asphaltum.

3. By replacing 10 per cent. of the cement with hydrated lime, to assist in filling voids and making the concrete more nearly impervious.

Erection.—Reinforced concrete buildings should be erected under at least the partial direction of the designer. In cold weather, material may be heated by piling it over steam pipes, the material pile being covered with canvas, and during working hours the part under construction may be enclosed by a curtain under which heat is maintained.

In joining new work to old, the hardened surface should first be cleaned till the aggregate is well exposed, and it should then be slushed with mortar consisting of one part of Portland cement

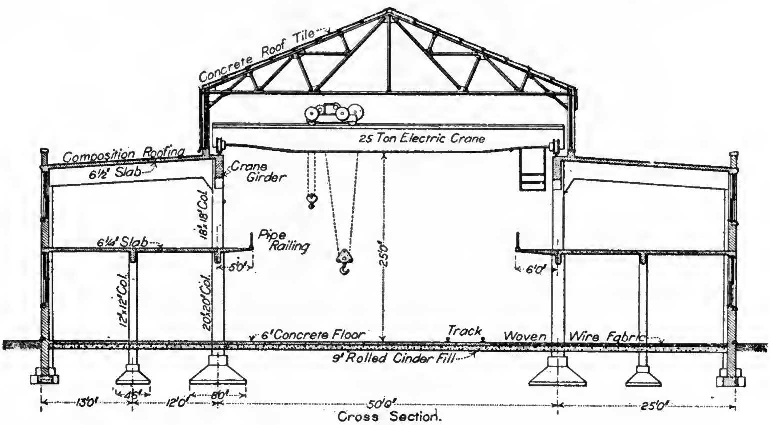


FIG. 71.—Reinforced concrete warehouse, Chicago.

with two parts of fine aggregate, before placing the new concrete. Expansion joints should be provided at intervals not exceeding 50 ft., and they should have overlapping or dovetailed joints. The concrete should be carefully inspected for hardness before the forms are removed. After the foundations are completed, reinforced concrete buildings can usually be erected at the rate of one story per week, and records show that large buildings to six to twelve stories can be erected complete in three to seven months.

Fig. 71 shows a concrete machinery warehouse in Chicago, with one tier of side gallery.

CHAPTER IX

CONCRETE SURFACE FINISH

The difficulty of producing esthetic and pleasing effects has until recently been one of the chief objections to concrete as a structural material in exposed positions. The many primitive and uncouth productions of the experimental years of its development, are still too evident about our large cities, and these obnoxious creations have often turned prospective builders to other and more attractive types. Factory buildings with bare gray walls, the monotony of which is broken only by unsightly form marks are rightly entitled to disapproval. Many of these buildings were erected before the methods of surface treatment were developed, while others are the result of supposed economy or deliberate disregard for appearances.

Surface Defects.—Some of the surface imperfections of concrete which must be avoided or removed, include efflorescence, cracks, irregularity of section, roughness, porosity, and dusting.

Efflorescence is supposed to result from a porous condition of the walls, allowing moisture to enter, for it is not found in dry positions. It would, therefore, appear desirable that walls be water tight, and methods of waterproofing concrete have already been given in a previous chapter. The most notable case of efflorescence removal is on the Connecticut Avenue bridge at Washington. Hydrochloric acid, diluted with five parts of water, was applied to the surface with scrubbing brushes, 30 gallons of acid and thirty-six brushes being used in cleaning 250 sq. yds. The average cost of the whole work, including the balustrades was 7 cents per square foot, but on plain surfaces the cost did not exceed $2\frac{1}{2}$ cents per square foot.

Hair Cracks.—The best means of preventing hair cracks is to use a comparatively dry and lean mixture not richer than one part of cement with four of sand, for it has been found that they increase rapidly with the proportion of cement. These

cracks are caused by cement on the surface hardening and shrinking more rapidly than that inside, and they can be partly avoided by keeping the surface covered with wet sand or saw dust. They are almost entirely absent on fine artificial stone, which is moulded in wet sand.

Porosity.—Porosity is caused by a lack of density, and if the outer and hardest layer is removed, the surface is more likely to leak. Walls which will admit water are liable to be disintegrated by frost in winter seasons, and the outer surface should not, therefore, be removed in cold climates.

Dusting.—This may be due to several causes, some of which are: Insufficient cement, soft sand, presence of foreign matter such as loam, poor mixing, partial setting of cement before finishing, excess of or not enough water in the surface mixture, or the use of driers to hasten setting. After such a condition has developed, it can best be remedied by applying two or three coats of boiled linseed oil.

Forms and Moulds.—Defects from forms and moulds are very common, and include irregularities from bulging or springing of the plank, joint marks or seams, roughness, and insufficient care in tamping the ingredients against the sides. To avoid leaving any impress on the masonry, the wood may be given a fine surface or may be coated with soap, grease, or paraffine, or covered over with building paper. These will also prevent the concrete from sticking to the wood. A sticky oil has sometimes been applied to the inner face of forms, and clean sand then blown over it from a bellows. This gives a uniform surface which appears on the concrete as a sand finish. A rather expensive method which has occasionally been used on important work, is to cover the forms with expanded metal and then coat with fine plaster, the resulting surface being so smooth as to avoid marks of any kind on the completed exterior. A similar but cheaper way is to cover the forms with fine clay and then overlay the clay with building paper. When concrete is deposited against the boards, unless they are otherwise covered, they should be wet with a hose to prevent absorption from the mixture which would result in too rapid or uneven drying. When exterior treatment is intended after the forms are removed, the above precautions are unnecessary, and indeed, a poorer grade of lumber can be used, thereby reducing this item of expense, which will to some extent offset the extra cost of after treatment.

Since it is difficult to avoid joint marks, they are sometimes accentuated by fastening small triangular strips over the cracks between the planks, leaving horizontal grooves on the masonry somewhat similar to stone joints. It is claimed by some that such markings are insincere and an effort at imitation, but if used wholly to efface unsightly lines, they would seem to have a sincere and truthful purpose.

Moulds for finer work have been made of wood, metal, sand and plaster of Paris. Artificial stone is usually cast in sand, the cement and fine crushed stone mixed in the consistency of soft cream, being poured into the sand and allowed to remain there for three or four days. The excess water from the mixture easily drains off through the sand and allows the stone to harden and dry uniformly without the formation of surface cracks.

Need of Treatment.—There appears to be only one process of building concrete in which an after treatment of the exposed surface is unnecessary, and that is by using a fairly dry and lean mixture on the face, with fine aggregate. With concrete of this kind, form marks do not appear when the boards are removed. A suitable mixture is composed of cement, sand and fine-crushed stone in the proportions by volume of 1, 1½ and 4½, the stone ranging in a size from ¼ to ½ in. For thin walls, this composition is used alone, but on thicker ones, it should form a facing about 1½ in. thick over ordinary concrete backing, the facing mixture being placed by using a movable metal shield, or by any of the other approved methods. The use of a dry mixture makes a wall that is more or less porous, but in Chicago where it is extensively used by the South Park Commission, after a trial of eight years, no injury from frost has been found.

Methods of Treatment.—The surface of concrete made with a wet mixture, and enough density when dry to be impervious to water, almost always shows imperfections of various kinds, some of which are form marks, roughness, cracks, and efflorescence, and these can be removed only by some kind of after treatment. After several years of careful experiment and investigation, a number of methods of treating and finishing concrete surfaces have been developed, which have proved satisfactory. These methods may be grouped into three general classes, (A) Surface Coating, (B) veneering, and (C) surface removal. These may be further subdivided as follows:

(A) Surface Coating.
    (1) Washing.
    (2) Painting.
(B) Veneering.
    (3) Brick, stone or Tile Facing.
    (4) Plastering.
    (5) Stucco Finish.
(C) Surface Removal.
    (6) Sand Blasting.
    (7) Tooling.
    (8) Rubbing.
    (9) Picking.
    (10) Scrubbing.
    (11) Pebble Dashing.
    (12) Acid Etching.

These methods are described somewhat in detail in the following pages. Before proceeding with his plans, the designer should first decide upon the type of finish which he prefers, as this will affect to some extent the actual construction.

Surface Coating

Washing with cement grout and painting, are the usual methods of surface coating, though both of them are carried out in many ways, differing from each other only enough to allow patent proprietors to establish their ownership.

Washing monolithic surfaces with cement or lime has the merit of low cost, but is only a poor substitute for something better, as it is not stable. Wherever possible, the thin grout should be applied with wooden floats, as brushes leave streaks. A cement wash is made by mixing three parts of natural or Portland cement with one part clean sand and enough water to make it easily applied. The mixture should be as thick as can be worked with a whitewash brush, and the whole should be well stirred before using. This will produce a gray color, the shade depending somewhat on the brand of cement. A grout of cement and plaster of Paris is also used and may be similarly applied. Brick color is obtained by adding 10 per cent. by weight of red iron ore, which should be mixed in at first. By increasing this proportion to 30 per cent. by weight, a dark red color results. Venetian red cannot be recommended, as it quickly fades. If a white surface is desired, the cement wash can first be applied in two coats and whitewash added afterward. These applications will adhere better when applied to concrete that is green or moist.

A good whitewash which is used on United States government lighthouses may be made by first slacking a bushel of lime with boiling water, and after it is strained adding half a bushel of salt previously dissolved and 6 lb. of ground rice boiled to a thin jelly, 1 lb. of powdered Spanish whiting, and 2 lb. of dissolved clear glue. It should be thoroughly stirred and mixed, and applied hot with a whitewash brush. The resulting surface is white instead of the gray finish from cement wash.

Whitewash is pure white lime mixed with water, and it adheres best when applied hot, but is easily washed off by rain and needs frequent renewals. The wash may be hardened to prevent cracking, by adding to each bushel of lime, 1 lb. of salt and 2 lb. of zinc sulphate. It may be tinted by adding to each bushel of lime, 4 to 6 lb. of ochre for cream color, 6 to 8 lb. of raw umber and 3 to 4 lb. of lamp black for buff or stone color, and 6 to 8 lb. of umber, 2 lb. of Indian red and 2 lb. of lamp black for fawn color.

Painting.—An oil paint suitable for walls is made by mixing one part each of white sand and quick lime with two parts of wood ashes, the whole being passed through a fine screen. To this mixture as a base, enough raw linseed oil may be added to make a thin paint which can be applied with a brush. If color is desired, it is added to the oil before mixing with the base.

Another oil paint for walls is made by mixing 100 lb. of clean sand, 100 lb. of white lead, 20 quarts of raw linseed oil, 4 lb. of raw umber, 1 lb. of drier and 1 pint of turpentine. When mixed to the proper consistency, it can be applied with a large brush.

An oil wall paint known as Bay State Cement Coating, has a cement base mixed with volatile oil which evaporates. It contains no lead, glue or water and is made in white or colors. It can be applied to a damp surface, will not absorb water, dries with a dull finish, and may be washed to remove dirt. It is made only in liquid form ready for use and never in a paste.

Concrete surfaces may be prepared for painting by coating them when dry with a mixture containing equal parts by weight of zinc sulphate and water applied with a brush. It should be allowed to dry for two or three days, after which paint can be applied over the cement the same as over ordinary plaster.

Veneering

Brick and Stone Veneering.—This is one of the oldest methods of facing concrete, for the Romans used it twenty centuries ago. Rubble masonry and concrete were often faced with tufa and travertine as on the bridges over the Tiber, and recent excavations at Pompeii have revealed concrete walls covered with marble slabs. Many of the finest works in France completed during the last half of the eighteenth and the first half of the nineteenth centuries, are made of concrete faced with stone. A comparatively recent bridge at Soissons is similarly faced with separately moulded concrete slabs. In America, some of the finest and latest manufacturing buildings have exterior concrete frames veneered with brick or previously moulded slabs of concrete. Good effects are produced by a judicious use of brick in different colors and by the use of colored tiles. Decorative work when used, should be concentrated in certain places to contrast with adjoining unbroken areas. Colored tiles can be cast with the concrete in large slabs and built in with the walls, or a space may be paneled out of the walls with forms, and the tiles set in afterward. Concrete blocks or artificial stones are used more for solid work than for surface facing, and are described elsewhere.

Plastering.—Plastering on concrete walls is not recommended, for it is stable only when moisture cannot reach the under surface and it rarely lasts more than ten to fifteen years even under favorable conditions. Before applying plaster, the concrete should be rough and clean, without scale or dust, and should be wet to prevent extracting water from the mortar before it hardens. The applied material should be pressed and worked well against the under surface to avoid open places or cavities which would quickly break.

A finish of comparatively recent use, known as Stonekote, is a mixture of Portland cement and white sand or white quartz containing no lime. In hardness, strength and durability it is nearly equal to natural stone and can be procured in several colors. Three coats of this mixture are recommended for use on sheathing and metal lath, with 100 lb. to $2\frac{1}{2}$ yd. of surface, and one finish coat on brick, concrete, or concrete blocks. It can be applied on a low-priced concrete wall, making a rough cast surface of the desired color, which may be waterproofed. Stonekote is slow in setting, but covers all joints if applied by

first-class workmen. The cost per square yard at Chicago is approximately as follows:

Natural color	28 cents per square yard
Colored second coat	32 cents per square yard
White second coat	36 cents per square yard
Rough cast, natural	37 cents per square yard
Rough cast, colored	38 cents per square yard
White on natural base	40 cents per square yard
Light colors on white base	42 cents per square yard

Exterior plaster and surface finish with expanded metal will cost from 75 to 90 cents per square yard.

Surface Removal

Preparation of Surface.—To produce aesthetic or pleasing surface effects, a special preparation must be made of the surface material before placing it, and the details of such preparation will depend upon the kind of surface that is desired. In most cases a fine aggregate should be used with cement sand and fine stone in the proportion by volume of 1, $1\frac{1}{2}$ and $2\frac{1}{2}$, with stones of $\frac{1}{8}$-in. to $\frac{1}{2}$-in. diameter. This mixture should be placed at the same time as the coarse backing so the two will unite, and to avoid hair cracking, it should not be richer than given above. The thickness of the facing surface should not be less than twice the size of the largest aggregate which it contains, and never less than 1 in. It should be fairly wet when placed, and yet firm enough so the large stones behind it will not be forced through. This facing when 1 in. thick, will cost from 2 to 4 cents per square foot, not including any after treatment.

Coloring.—Coloring can be affected either by the use of certain kinds of sand and stone, or from pigments. No kind of fancy aggregate is of any advantage unless the surface is treated after forms are removed, for they all have the same leaden gray shade of the cement in which they are enveloped. Sand can be either gray, white or yellow and stone is obtainable in great variety of colors. A mixture of white and black marble or trap rock makes a pleasing contrast, while brighter effects are obtained from colored marbles or red granite. Other hard material such as broken brick, burnt clay or tiles may be added, and all of these can be crushed to any desired size, and colors mixed to suit the taste of the designer or his sense of beauty and fitness.

Natural coloring is preferable to artificial, and yet when colored aggregate is not obtainable, pigments may be used. Mineral pigments only are suitable, because vegetable colors are not permanent. Red, yellow, blue and black are the best. Some common pigments with their approximate cost are given in Table VIII.

Buff color made from yellow ochre and mineral red is a favorite, and a mixture of carbon black with red iron ore gives a dull red, while the addition of lamp black to the last produces a darker effect. Lime is generally used for whitening. As the presence of pigments tends to lessen the strength of concrete, the amount of pigment should be limited to 5 per cent. by weight of the cement, or 5 lb. per bag. A less amount than this will give lighter shades. The cement aggregate and pigment should all be mixed together dry, and it should be observed that mortar when wet is darker than when it is dry.

TABLE VIII

Color desired	Commercial names of colors for use in cement	Approximate prices per pound in 100-lb. lots for high-grade colors	Pounds color required for each bag of cement to secure	
			Light shade	Medium shade
Grays, blue-black and black.	Germantown lampblack.	10 cents	½	1
	Carbon black	8 cents	½	1
	Black oxide of manganese.	6 cents	1	2
Blue shade	Ultramarine blue	18 cents	5	10
Brownish-red to dull brick red.	Red oxide of iron	3 cents	5	10
Bright red to vermilion.	Mineral Turkey red.	15 cents	5	10
Red sandstone to purplish-red.	Indian red	10 cents	5	10
Brown to reddish-brown.	Metallic brown (oxide).	4 cents	5	10
Buff, colonial tint, and yellow.	Yellow ocher	6 cents	5	10

Before starting construction, it is worth while experimenting on samples to get the color effect and surface finish that is satisfying, and when proportions have been established, they should be closely adhered to, as slight variation in successive batches of concrete may give shades that are quite noticeably different. The proportion should, therefore, be measured, and not simply gauged by the number of barrows. Coloring with pigments will usually cost from $\frac{1}{2}$ to 2 cents per square foot.

Removal of Surface.—Defects and irregularities on concrete surfaces can be removed by the sand blast, or by tooling, rubbing, picking, scrubbing or etching with acid. The objection to any kind of surface removal is the loss of the outer and hardest part of the mortar, which removal may allow water to enter. Roughening the surface by any of the processes just mentioned causes the building to more easily collect grime and dust, but as concrete buildings are usually of a smoky gray, such dust collection may not be very noticeable.

Sand Blasting.—This method is economical only for large areas. It cannot be undertaken in less than ten days or two weeks after the concrete is placed, and a longer time of about a month is often preferable. For this reason, it is suitable for the underside of girders or arches where forms supporting weight cannot be removed in less than thirty days. Air should have a pressure at the nozzle of 50 to 80 lb. per square inch, and the nozzle should not be larger than $\frac{1}{8}$ to $\frac{1}{4}$ in. diameter, for if greater, the jet of sand cannot be concentrated on small defects. Sand should be clean and hard and of a size to pass a No. 12 screen for $\frac{1}{8}$-in. nozzle, and a No. 8 screen for $\frac{1}{4}$-in. nozzle. The cutting action of the sand removes the surface film of cement at a cost of about 3 cents per square foot. Work can usually be done by, or with apparatus from, some company of building cleaners.

Tooling.—Tooling, to remove about $\frac{1}{16}$ in. from the surface may be done either by hand or pneumatic process, hand work being cheaper for small jobs, and especially for low walls where scaffolding is not needed. For large areas, high above ground, air tools will probably be cheaper than hand work by 30 to 50 per cent. The concrete should be two to three weeks old and the best results are usually obtained from a fine aggregate. If large stones lie near the surface, the concrete should be at least two months old, to prevent stones from being knocked out by the tools instead of being cut. One laborer will dress from 50

to 100 sq. ft. per day when concrete has not been placed longer than two to three weeks, the cost for hand work being from $1\frac{3}{4}$ to $3\frac{1}{2}$ cents per square foot, not including staging, or as low as $1\frac{1}{2}$ cents per square foot when labor wages do not exceed $1.50 per day. Bush hammering can be done quite as well by common as by skilled labor, though in some cases, the better grade of labor has been used in accordance with regula-

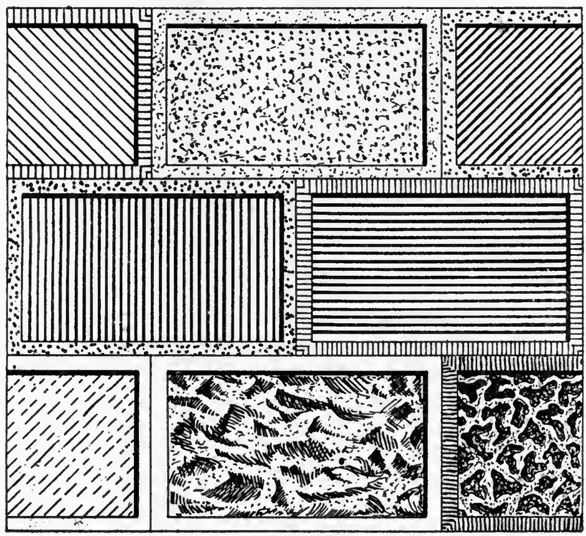


Fig. 72.

tions of labor unions and frequently on government work. Tooling such as generally used on Bedford or similar stone can be done to the best advantage when the concrete has a fine mortar face and has thoroughly hardened. In this case experienced stone cutters are needed. Machine work with pneumatic tools can be done at the rate of 300 to 600 superficial feet per man per day, at a cost on large areas of $1\frac{1}{2}$ to 3 cents per square foot, with labor wages at $2 per day. Those who have done this kind of work extensively, recommend the more liberal allowance of 3 to 4 cents per square foot for green surfaces and 5 to 10 cents per square foot for hard surfaces.

Some tooling effects are shown in Fig. 72.

Rubbing.—In this method, the surface is rubbed or ground with a brick, a block of sandstone or carborundum, after the forms have been removed, which should be between six and forty-eight hours after placing. To facilitate grinding, a wash of cement and sand mixed in the proportion of 1 to 2, should be used between the wall and the grinding stone. As lather forms it may be washed off, and the grinding process continued after applying more cement and sand. When rubbing is done with carborundum, a No. 16 stone is most appropriate for the first application, but the finishing should be done with a No. 30. This method is most suitable for fine mortar facing and when soft stone such as marble is used in the aggregate, the process being similar to that used in finishing a Terrazza floor. The cost should not exceed 1½ to 2 cents per square foot, or 4 cents, with carborundum. A variation of this method is to cut the surface with sand rubbed on with a plasterer's float, using plenty of water, in which case a laborer can wash and clean 100 sq. ft. per hour.

Picking.—This work can be done either by hand or pneumatic tools. Within three or four days after the concrete is placed a laborer can do four times as great an area as he could when concrete is only two weeks old. The costs are, therefore, as follows:

Picking concrete.....	6 to 24 hours old.....	1 cent per square foot.
Picking concrete.....	2 days old...........	2 to 3 cents per square foot.

Picking makes a rougher and coarser surface when green than when dry, and experience shows that one man with air tools can dress 400 to 500 sq. ft. per day.

Scrubbing.—In this method, while the concrete is still green the surface is washed with stiff brushes to remove enough of the cement that the stone and aggregate may be plainly exposed. Aggregate in the facing mixture, which should be at least 1 in. thick, may consist of pebbles, fine-crushed granite, trap rock, broken brick, or a mixture of several kinds of stone and these materials can be plainly exposed when a little of the cement is washed away (Figs. 73–78). The rate at which work can be done will depend largely on the hardness which the concrete has attained. For different climatic conditions, the time of form removal should be as follows:

In hot weather, remove forms in..................	24 hours.
In cooler weather, remove forms in...............	2 to 3 days.
In cold and wet weather, remove forms in.........	6 to 7 days.

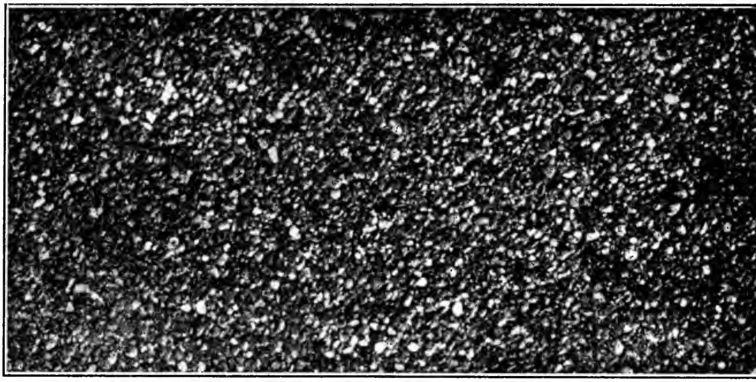


FIG. 73.—Scrubbed and etched surface of 1–3 fine sand mortar.

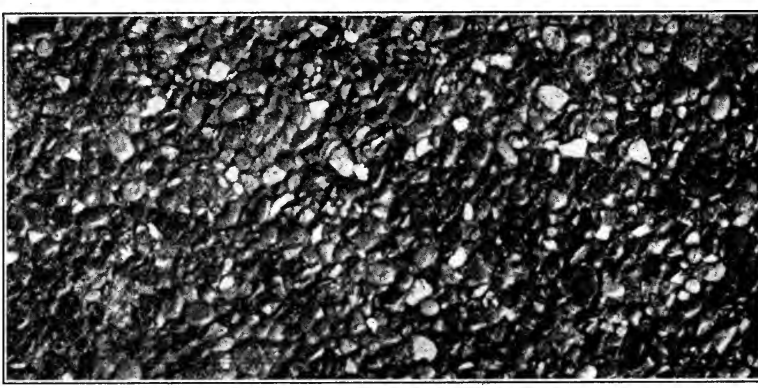


FIG. 74.—Scrubbed and etched surface of 1–3 coarse sand mortar.

FIG. 75.—Scrubbed and etched surface of 1–3 small pebble mixture.

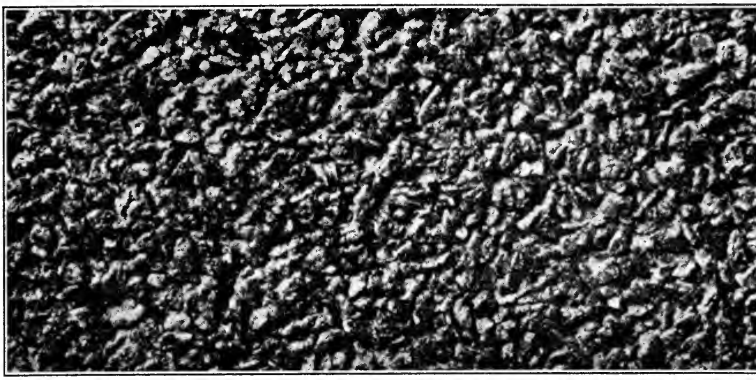


FIG. 76.—Scrubbed and etched surface of 1–2½ mixture of fine granite screenings.

FIG. 77.—Scrubbed and etched surface of 1–2½ mixture coarse granite screenings.

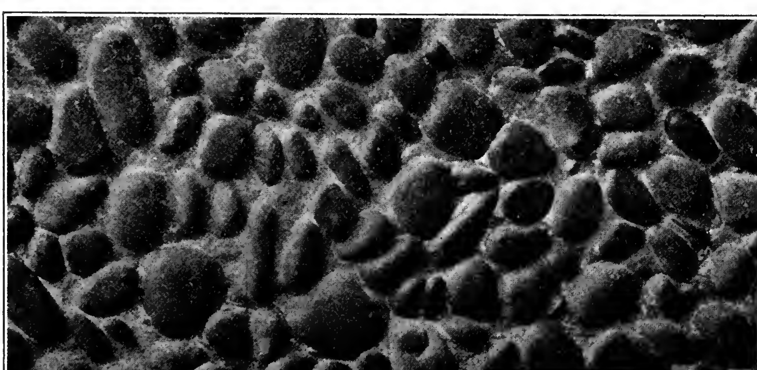


FIG. 78.—Scrubbed and etched surface of 1–2½ mixture of coarse pebbles.

The above rule applies only to face work, where the forms support no dead load. Under beams or floors they must usually remain in place for at least a month. When this work is done with cement at the right degree of hardness, a man can wash out enough of the surface with three or four passages of an ordinary kitchen scrubbing brush. The work must not be undertaken too soon, for stones might then be dislocated leaving unsightly holes, and on the other hand, if delayed too long the work is slower and more expensive. In some cases it can be done in eight to ten hours after the concrete is placed, but when delayed too long, wire brushes may be needed.

By this method quite a variety of effects can be produced by using stone of different size and color, and the result is a truthful expression of concrete construction, exhibiting as it does, the very make-up of the material. The effect is improved if, after scrubbing, the surface is washed with hydrochloric acid mixed with five times its volume of water. This cleans the aggregate and brightens the color, but the face must afterward be thoroughly washed with a hose to avoid future discoloration. Any kind of limestone or marble which would be attacked by acid cannot be used when etching is intended. Forms should be taken down only fast enough to keep an hour's work ahead of the scrubbers, and on vertical surfaces this can be arranged by setting the studs out from the forms on blocks, which are easily knocked out as needed, allowing the boards to be taken away. When done at the right time, a man can scrub 100 sq. ft. per hour, though it may take him two to five times as long if the work is delayed until the cement is hard.

An effect somewhat similar to that described above, can be obtained by plastering the inside face of the outer form boards with stiff clay ½ in. thick, and embedding in the clay a layer of pebbles of random size, laid close together. Concrete is then poured in and tamped against this facing. After twenty-four hours, the forms are removed and the clay washed away with a brush and hose, leaving the pebbles exposed, which are now a part of the concrete wall.

Acid Etching.—The exterior film of cement on concrete walls may also be removed wholly by acid etching, but the acid must be used with care, for if not thoroughly washed off afterward, discoloration will develop. When this process is intended, the aggregate must contain no limestone or marble, as these would

be attacked and decomposed by acid. Either hydrochloric or sulphuric acid may be used, though the former is usually preferred, and the strength will depend upon the age of the composition. When concrete is only two days old, the acid may be diluted with five or six times its volume of water, but when two weeks old, the acid should be twice as strong. At the end of thirty days, the mixture should combine one part of acid with two of water, and the liquid may be allowed to remain on the surface for thirty minutes before washing it away. Concrete made with white sand and fine crushed stone, after being etched in this way to remove the outer film of cement, gives the appearance of fine finished white stone.

CHAPTER X

COST OF REINFORCED CONCRETE BUILDINGS[1]

The most recent report of specific costs of reinforced concrete factory buildings is that presented at the convention of the National Association of Cement Users in March, 1912. These costs in detail are given in Table IX.

From this table it appears that the average cost of single-story buildings with saw-tooth roof is $1.77 per square foot of floor and 8½ cents per cubic foot of contents, while the average cost of buildings with more than one story is $1.12 per square foot or 8.7 cents per cubic foot of contents. These figures are on the complete building with plumbing, but they do not include heating, lighting, sprinkler system, elevators or power equipment. The square foot prices were obtained by dividing the total cost of the building by the aggregate floor area including the basement, but not including the roof.

Another report on the cost of reinforced concrete buildings read in 1909 before the National Association of Cement Users gives the specific costs of a number of buildings, which are shown in Table X.

From this table it appears that the average cost of twenty-one buildings was $1.72 per square foot of floor area, and 13.8 cents per cubic foot of contents. This table is followed by a detailed cost analysis of forms and concrete in place, which is reproduced in Table XI.

It appears, therefore, that the average cost of forms per square foot, is for columns 13 cents, beam floors 11.6 cents, slab floors 11.1 cents, slabs only between steel beams 9.5 cents, walls above ground 12.8 cents, foundations 10.3 cents, and footings 9.3 cents.

A subdivision giving the percentage cost of concrete, steel, labor and forms is as follows:

Concrete,	costs	19 per cent. of the total
Steel,	costs	17 per cent. of the total
Labor,	costs	31 per cent. of the total
Forms,	costs	33 per cent. of the total
	Total....	100 per cent.

[1] H. G. Tyrrell, in *Engineering Magazine*, June, 1912.

TABLE IX.—COST OF REINFORCED CONCRETE INDUSTRIAL BUILDINGS

Type	Size ft.	No. of stories	Height of stories ft. in.	Live load lbs.	Kind of floor	Column spacing ft.	Costs	
							Per sq. ft.	Per cu. ft.
Machine shop	50×120	4	12–6	150	Beam and slab	10×24	$1.17	$.09
Cotton mill	129×550	2	16	75	Beam and slab	10–8×25	.98	.07
....	....	4	12–6	150	Flat slab	17×20	1.09	.077
Weave mill	60×140	5	12–6	150	Flat slab	17–6×20	1.50	.12
Knitting mill	75×220	2	14	125	Beam and slab	12×25	1.09	.073
Factory	56×223	2	16	300	Beam and slab	18–6×18–6	1.55	.10
Weave shed	231×341	1	....	125	Saw tooth	13×21–4	1.79	.07
Machine shop	100×220	1	....	....	Saw tooth	20×20	1.75	.10
Storehouse	56×181	4	14–6	150	Flat slab	18×20	1.15	.07
Storehouse	109×580	10	12	250	Beam and slab	19–3×19	.85	.071
Storehouse	....	....	....	....	....	....	.76	.05
Storehouse	100×256	12	8	150	Flat slab	16×16–8	1.04	.12

TABLE X.—COST OF CONCRETE BUILDINGS

Type	Place	Total cost of bldg.	Volume in cubic feet	Floor area, sq. ft.	Costs	
					Cu. ft.	Sq. ft.
Store	Nashua	$141,755	1,714,400	168,696	$.0827	$.84
Hospital	Buffalo	60,800	703,692	57,654	.0865	1.05
Office	Everett	61,646	496,780	39,840	.124	1.545
Cold store	Boston	200,051	1,535,000	154,000	.13	1.30
Factory	Chelsea	19,292	212,400	15,000	.091	1.28
Factory	Cambridge	141,529	1,329,868	106,000	.107	1.335
Storehouse	Saco	76,796	1,140,000	146,000	.0685	.575
Factory	Providence	91,377	1,380,500	90,240	.067	1.01
Office	Jacksonville	136,880	693,840	56,552	.197	2.42
Factory	Cambridge	133,064	105,600	8,800	.124	1.485
Factory	Cambridge	75,604	1,211,364	75,604	.0625	1.01
Factory	Cambridge	23,332	180,000	16,394	.129	1.42
Office	Portland	181,194	1,365,800	90,474	.133	2.00
Factory	Greenfield	12,774	112,440	7,519	.114	1.70
Factory	Southbridge	44,652	746,674	49,546	.060	.902
Factory	Attleboro	39,830	312,000	24,960	.127	1.60
Garage	Brookline	10,436	156,198	10,806	.085	1.23
Filter	Lawrence	19,993	149,250	19,208	.134	1.04
Fire station	Weston	6,757	44,265	2,982	.153	2.26
Observatory	Milton	3,625	9,734	657	.373	5.45
Filter	Lawrence	20,076	59,991	5,243	.333	3.82
Average					.138	1.72

This analysis assumes that materials can be delivered at the site on cars, and that form lumber can be used twice. As two-thirds of the total cost is for labor and forms, and one-third for the forms alone, it is economical where time will permit, to use forms more than twice, or as often as the lumber will last. Repetition and duplication of forms are, in fact, the greatest factors in cost reduction, and the design should be so made that this is possible. The average cost of forms obtained from a different set of records from those given above, is, for floors with beams, girders and slabs, 10 cents per square foot, and for flat slab floors without beams 7 cents per square foot. The corresponding cost of column forms is 13 cents per square foot. The cost of bending and placing reinforcing steel, including wire mesh in slabs, varies from $5 to $17 per ton, the average being about $10 per ton.

A reinforced concrete building designed by the writer, 55 ft. wide and 88 ft. long with seven stories and basement and 500,000 cu. ft. of contents, cost $1.15 per square foot of floor, or 9.1 cents per cubic foot of contents. The floors were proportioned for

TABLE XI.—COST ANALYSIS OF FORMS AND CONCRETE (AVERAGE RESULTS)

	Cost of forms per square foot of surface				Cost of concrete per cubic foot in place						
	Labor	Lumber	Nails	Total	Concrete labor	General labor	Cement	Aggregate	Teaming	Plant	Total
Columns	.082	.036	.001	.130	.096	.027	.085	.049	.021	.023	.301
Beam floors	.070	.045	.002	.116	.111	.020	.106	.063	.025	.024	.354
Slab floors	.071	.038	.002	.111	.097	.009	.096	.070	.019	.024	.315
Slabs only	.061	.032	.002	.095	.102	.019	.128	.068	.024	.017	.359
Walls	.085	.036	.002	.128	.090	.016	.073	.076	.025	.019	.301
Foundation	.068	.033	.002	.103	.076	.015	.080	.062	.019	.017	.269
Footings	.057	.034	.002	.093	.045	.007	.071	.077	.007	.021	.229

a total load of 200 lb. per square foot, and the prices given above include excavation, foundations, walls, columns, floors, framing, roofing, windows, doors and stairs, but do not include plumbing, elevators, heating, lighting, or partitions.

Concrete factory buildings from one to five stories in height and about 50 ft. wide, will have minimum costs about as follows:

	Cost per square foot of floor area	Cost in cents per cubic foot of contents
3, 4 and 5 stories	\$1.00 to \$1.10	7.5 to 8.5
2 stories	1.05 to 1.15	8.0 to 9.0
1 story	1.10 to 1.20	8.5 to 10.0

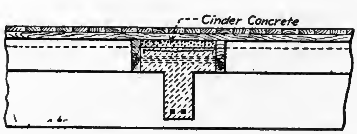
These prices do not include partitions, plumbing, heating, lighting or elevators. In the South or in country districts where labor is cheaper, the unit costs may occasionally be 10 to 15 per cent. less. But when buildings are erected by contractors who are only occasionally employed on such work, the cost is likely to exceed the minimum prices given above, and amount to \$1.30 per square foot for buildings of three stories or more, to \$1.60 per square foot for those with only single stories. Concrete framing, including slabs, beams and columns only, without walls, costs from 45 to 65 cents per square foot of floor area.

The cost of reinforced concrete buildings from numerous designs and estimates made by the writer (see Tyrrell's Mill Buildings) varies from 6 to 12 cents per cubic foot for factories and warehouses, and from 10 to 16 cents per cubic foot for stores and loft buildings. These are based upon the use of complete concrete frames and exterior curtain walls, without power, heat, light, elevators or interior finish. Buildings with concrete slabs and 2-in. cement finish, costing \$1.25 per square foot, would with cement finish on 2-in. cinder concrete, cost about \$1.30 per square foot, and \$1.35 per sq. ft. with $\frac{7}{8}$ maple on 2-in. cinder concrete, with a concrete floor slab in each case. (See Concrete Floors.)

A two-story reinforced concrete factory building 100 ft. square, at Walkerville, Ontario, with 6-in. curtain walls, and columns 16 ft. apart in both directions, cost complete, including concrete, rods and forms, \$19.88 per cubic yard of concrete in place.

Some contractors use the following method of estimating the cost per cubic yard of all material in place. First find the cost, delivered at the site, of the cement, sand and stone required for a cubic yard of concrete, and to this add $5 per yard for the reinforcing metal. The sum of these two costs is assumed to represent one-half of the total per cubic yard of the materials in place. The labor of mixing and placing the concrete and of placing the steel will add one-third to the above sum, and the material and labor on forms will be two-thirds more. The resulting cost does not include contractor's profit or plant depreciation. General expense and cleaning up after completion may be $1 to $2 per cubic yard additional.

A considerable saving in the cost of reinforced concrete buildings can be affected by omitting the floor slabs, and using a frame of columns and girders only, with a double course of boards supported on reinforced concrete beams (Fig. 79). As previously noted, a four-story office building of this kind at Fore River, Mass., a large part of the curtain



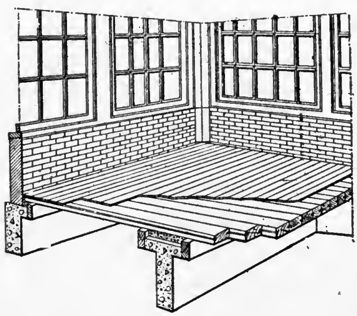


Fig. 79.—Reinforced concrete beams with wood floor.

walls being glass, cost with the foundations, walls, roof and floors, only 63 cents per square foot of floor area, or 4½ cents per cubic foot of contents. Including lighting, heating, toilets and partitions the cost was $1.30 per square foot of floor, or 9.2 cents per cubic foot. Another similar five-story building in the same state, 50 by 300, cost only 7.6 cents per cubic foot.

Economy often results also from the use of separately moulded floor members, a good example being the cold storage warehouse at Syracuse, previously described. The building was six stories high, and 78 feet square, and concrete floors of the Watson system (Fig. 65) were supported by a frame of steel beams and columns. The floors alone cost 20.5 cents per square foot, and the steel framing and fireproofing 21.5 cents additional, or a total of 42 cents per square foot of floor area, and 4 cents per

10

cubic foot of volume for both floor and frame. Including the gravel roof, curtain walls and stairs, the cost was 61 cents per square foot, or 5.7 cents per cubic foot, the granolithic floor finish, and wall plastering not being included. In determining these unit prices, the area of six floors and basement, was taken inside of the exterior walls.

Much of the published information in reference to the cost of concrete work is based upon the records of well-organized building companies who are equipped to do such work in the most economical manner. Other builders with less facilities should therefore be liberal in their estimates. Some contractors when estimating use a cost unit for reinforced concrete of $1 per cubic foot or $27 per cubic yard for all material in place, which is no doubt large enough for even inexperienced builders. (For other costs, see "Reinforced Concrete Floors.")

CHAPTER XI

COMPARATIVE COST OF WOOD, REINFORCED CONCRETE AND STEEL BUILDINGS

Where wooden buildings are referred to in the following comparisons, only mill construction of the slow burning type is considered, for nearly all modern industrial enterprises are housed in buildings that are to some extent fireproof. The question may reasonably be asked here, what constitutes a fireproof building? Nothing is more fireproof than a furnace and yet the decomposition of its contents by fire is its chief use. These buildings must, therefore, not only be made of non-inflammable material but they must be so arranged that fire when started can be confined to one room or to the smallest possible space. With this object in view, they should be equipped with self-closing metal doors, and windows with wire glass or metal shutters. They should have automatic fire alarms, and above all an adequate sprinkler system. Steel framing must be enclosed and protected with some material such as brick, tile, terra-cotta or concrete. Under these conditions with insurance on the contents, a manufacturing enterprise is reasonably safe.

Building types arranged in order of their relative first cost are as follows:

A. Complete steel frame, fireproofed, with curtain walls and plank floor.

B. Interior steel frame, fireproofed, with solid brick walls and plank floor.

C. Complete steel frame, fireproofed, with curtain walls and reinforced concrete floors.

D. Interior steel frame, fireproofed, with solid brick walls and reinforced concrete floors.

E. Entire reinforced concrete building.

F. Part interior steel frame, not fireproofed, with solid brick walls and wood mill floors.

G. Entire wood mill construction.

The first cost is, however, not always the governing consideration, for in these times of large enterprises, any reasonable investment is permissible which will result in ultimate economy, when the expenses of maintenance, depreciation, interest and insurance are considered. The selection of a building type is, indeed, a choice of the most profitable investment.

The annual depreciation of wood mill buildings is usually assumed at 1 to $1\frac{1}{2}$ per cent. of their first cost, and the corresponding depreciation of concrete buildings would probably not exceed half of 1 per cent., though on this subject there is little reliable information as the type is comparatively new. Oscillation and vibration in building frames of wood and steel, cause a further loss in machinery repairs and increased power, which is variously estimated at 1/2 to 1 per cent. of their first cost, and this loss is avoided by the use of rigid framing such as concrete. Fireproof types have a slight advantage also over wood construction in the matter of sanitation and light, for more wall area is available for windows, and rats, mice and other vermin have less chance to collect and live.

In comparing the first cost of buildings in wood mill construction and in reinforced concrete, it will be found that their relative cost varies with the location, size of building and the floor loads to be sustained. In the Southern States, or other regions where timber is abundant and cheap, wood construction will often cost 25 to 30 per cent. less than reinforced concrete, while in districts where wood is scarce, the two types may be nearly equal.

The comparison depends also on the size of the building, for large ones have often been found to cost about the same in either material, and small ones are sometimes more expensive by 30, 40 or 50 per cent. in reinforced concrete than in wood. The required floor capacity also affects the comparison. Light loads with long spans are cheaper in wood mill construction than in reinforced concrete, the cost of the two types being nearly equal in large buildings with 200-lb. imposed loads per square foot, and column spacing of 18 to 20 ft. With loads of 300 to 500 lb. per square foot, concrete becomes the cheaper, and the saving increases rapidly with greater loads of 1000 to 1200 lb. per square foot.

A concrete building designed by the writer and containing about 500,000 cu. ft., was found to cost 17 per cent. more than

one in wood mill construction, and about the same as a building with complete interior fireproofed steel frame, solid walls and wood floors. It was in Ohio, and the total floor load, including both live and dead, was 200 lb. per square foot. (See Tyrrell's Mill Buildings, p. 62.)

As a general rule, therefore, it will be found that reinforced concrete in the Northern States, costs about the same as wood for large buildings, worth $250,000 or more, with heavy loads. Those worth $25,000 to $100,000 will usually cost 10 to 20 per cent. more in concrete than in wood, and small structures, especially for light loads, may be cheaper in wood by 30, 40, or even 50 per cent.

The following table gives a miscellaneous lot of bids and estimates on manufacturing buildings, with comparative costs in wood mill construction and in reinforced concrete. It will be seen that the costs in most cases are from 1 to 27 per cent. higher in concrete than in wood, though two of them are cheaper in concrete.

TABLE XII.—COMPARATIVE COST OF WOOD MILL CONSTRUCTION AND REINFORCED CONCRETE BUILDINGS

Kind	Place	Size ft.	Stories	Load lbs.	Cost of wood bldg.	Cost of concrete bldg.	Concrete more or less than wood %	
Factory....	Detroit.....	....	3	300	$28,200	$28,500	1.5 more	Bid
Factory....	Jersey City..	60×140	5	200	52,000	56,000	7.1 more	Bid
Factory....	Grand Rapids	....	......	.....	85,300	86,000	1.3 more	Bid
Factory....	Fall River...	112×112	4	.....	74,000	82,500	10.3 more	Bid
Factory....	Manchester.	45×100	5	.....	52,000	72,000	27.7 more	Est.
Warehouse	Boston......	20×155	9	.....	212,500	196,000	6.3 less	Bid
Warehouse	Jersey City..	38× 94	6	200	39,000	43,000	9.3 more	Bid
Warehouse	Pittsburg....	100×120	4	.....	61,500	63,600	3.3 more	Bid
Warehouse	Nashua.....	100×200	8	.....	117,000	131,000	10.7 more	Bid
Press bldg..	Cincinnati...	....	......	.....	....	....	4.0 more	Bid
Bakery....	Cincinnati...	60,000 s.f.	......	300	64,000	62,500	2.3 less	Bid
Shop......	Cincinnati...	....	......	.....	16,000	19,100	16.2 more	Est.
Shop......	New England	....	......	.....	65,800	69,500	5.2 more	Est.

Comparing now the *ultimate* cost of the two types. For convenience, a wooden building will be assumed at $100,000, and a concrete building 10 per cent. more or $110,000, and the contents in each case will be assumed of equal value to the building. The yearly maintenance cost of each will therefore be as follows:

	Wood	Reinforced concrete	
Depreciation at 1 1/2 per cent	$1,500	at 1/2 per cent	$ 500
Insurance on bldg. at 80 cents	800	at 20 cents	220
Insurance on contents at $1.10	1,100	at 80 cents	880
Interest and taxes at 7 per cent	7,000		7,700
Oscillation, vibration at 1 per cent	1,000		......
Total	$11,400		$9,300

The reinforced concrete building costing $110,000 will then have a maintenance cost of $2100 per year, or 2.1 per cent. less than the wooden one at $100,000, and this difference of $2100 at 6 per cent., is interest on $35,000. It would, therefore, be permissible to invest an additional $35,000 on a concrete building, to make the two types of equal ultimate cost. A concrete building costing $145,000 or 45 per cent. more, has therefore no greater ultimate cost than a wooden one at $100,000.

In comparing the cost of fireproofed steel construction with reinforced concrete, complete framing and exterior curtain walls being considered in both cases, it will be found that for imposed floor loads of 150 lb. per square foot or more, concrete will be cheaper than steel by 5 to 20 per cent., depending on conditions. For light loads, the cost of the two types will be nearly equal, and in some cases with very light load and long spans, steel framing will be slightly cheaper. One-story buildings over large areas are best when framed in steel.

A comparison made by the writer, on a building costing about $50,000, for total floor loads of 200 lb. per square foot, showed that one with fireproofed steel framing and heavy wooden floor, cost 12 per cent. more than one of reinforced concrete with granolithic floor surface. It appears, therefore, that factory buildings of reinforced concrete have the lowest cost of any fireproof construction that is yet available.

The following table gives the comparative cost of a variety of buildings of different kinds, in both reinforced concrete and in steel. It shows that the former type is cheaper than the latter by 3 to 13 per cent.

From comparative estimates made by the writer for a building of 500,000 cu. ft., to determine the comparative cost of fireproofed steel construction and wood mill framing, it appears that one with complete fireproofed steel frame, side curtain walls and wood floors, costs 30 per cent. more than wood mill construction, while the same building with only interior fire-

TABLE XIII.—COMPARATIVE COST OF BUILDINGS IN REINFORCED CONCRETE AND IN STEEL[1]

Kind	Place	Size ft.	Stories	Load lbs.	Cost of reinforced concrete	Cost of steel	Re-con. more or less than steel	
Factory....	Des Moines..	66×132	6	200	$60,650	$69,750	13% less....	Est.
Factory....	Fairmount...	50×100	3	200	25,000	28,000	10.7 less....	Bid
Warehouse	Brooklyn....	140×190	10	200	250,000	280,000	10.7 less....	Bid
Office......	St. Louis....	86×120	8	70	170,000	184,000	7.6 less....	Bid
Office......	Cincinnati...	....	17	70	....	....	4.0 less....	Bid
Mill.......	Boston......	....	3	.....	278,200	286,400	2.8 less....	Bid
	Cambridge..	60×320	5	.....	90,000	87,300	3.3 more..	Bid
Store......	Indianapolis.	71×120	6	125	89,500	96,000	6.8 less....	Bid
Hospital...	Indianapolis.	....	6	.....	793,000	823,000	3.6 less....	Bid
Hotel......	St. Louis....	120×140	8	70	171,000	184,000	7.0 less....	Bid
Hotel......	St. Louis....	....	11	70	290,000	304,000	4.6 less....	Bid
Factory....	Ohio........	....	12	200	40,000	less than	steel........	Bid
Loft.......	Springfield..	105×283	9	150	280,000	320,000	12.5 less....	Bid

proofed steel frame and solid bearing walls, cost 19 per cent. more than wood. If the first building mentioned above had a reinforced concrete floor, its cost would be 37 per cent. more than wood mill construction, while the corresponding cost of the second one with reinforced concrete floor would be 26 per cent. more.

[1] J. P. H. Perry, in *Engineering Magazine*, July, 1911.

CHAPTER XII

FOUNDATIONS

Permanent buildings should have substantial foundations, for on them depends the stability of the whole erection. Under this heading is considered the sub-strata or soil on which the building stands as well as the footing courses or masonry below ground level. Foundations for factory buildings are usually not difficult, for a site will have been selected with due regard for economy in this direction, so the subject will be discussed only briefly. Any effort at exhaustive treatment would in itself, fill a whole volume. Foundations must be provided not only for the buildings, but also for machinery, yard cranes, water towers and other works about the plant, and enough foresight must be used to provide space or openings through the walls for power tunnels or for lines of pipe, sewers, service mains or conduits.

Loads.—The loads which the foundations must sustain can be computed approximately from preliminary building plans, and from the weight of machinery and appliances as reported by their makers. Floor loads will have been established, and these, together with their dead weight, will be transmitted through the framing to the ground. From the known weight of masonry and other building materials and the approximate rules for weight of framing as given in previous chapters, the total weight on the soil can be determined. Impact from cranes and machinery, to the extent of 50 to 100 per cent. of the live load, must in some cases be added, and sometimes the overturning effect of wind on the leaward side.

Bearing Power of Soils.—The best method of determining the safe bearing power of soils, is by loading small known areas and observing the settlement. In many cases this may not be necessary, as an experienced builder can decide the matter by inspection or by very simple examination. But when there is any doubt, tests or borings should be made. So many buildings have been permanently injured by uneven settlement, that it is folly to assume risks in this direction when the condition of the

ground can easily be found at slight expense. When soundings are desirable, they should be made *under* the site of the proposed building and not simply near it. The best method of discovering soil conditions is by digging test pits, though a quicker way is with a large wood auger fastened to a rod or pipe. The test pit gives the greatest opportunity for examining the strata.

For the purpose of taking soundings, sections of pipe about $1\frac{1}{2}$ inches diameter, can be driven into the ground with the assistance of a water jet when necessary, the driving being done with a wooden mallet. The upper end of the pipe should be protected by a cap, and new sections of pipe may be spliced as needed.

The safe bearing value of different kinds of soil, as used by the United States government engineers, is as follows:

TABLE XIV

Rock	200 tons per square foot
Gravel, cemented	8 to 10 tons per square foot
Sand, compact and clean	4 to 6 tons per square foot
Sand, ordinary	2 to 4 tons per square foot
Dry stiff clay	4 to 6 tons per square foot
Moderately dry clay	2 to 4 tons per square foot
Dry earth	1 to 2 tons per square foot
Quicksand and wet soil	1/2 to 1 ton per square foot

The bearing power of soils may sometimes be increased by draining, or compressing the earth, or a firmer strata may be found at greater depth. In other cases piles may be driven.

Area on the Soil.—From the nature of the ground as revealed by soundings or test pits, a safe bearing load per square foot can be determined, and from the weight of the building as found by computation, the area of base can be proportioned. Foundation loads are rarely assumed greater than 1 to 2 tons per square foot.

In proportioning the foundation area to the load upon it, an effort need not be made to eliminate all settlement, but rather to so plan the building that whatever settlement does take place, will be uniform. With this in mind it will be seen that it is often as great an injury to make some parts too large as it would be to make them small, for they would then not settle at the same rate. Rock foundation is satisfactory when it underlies the whole building, though cranes and machinery may run easier when founded on earth or timber. Rock under some parts and

earth under other parts, is not desirable, for the first is unyielding while earth will compress, to some extent. Therefore, in passing from rock to earth, the footing courses should be spread out over the softer material so the pressure per square foot on the soil adjoining the rock will be less than it is further away. Sloping rock must be dressed off into horizontal steps. Loam is seldom reliable, and sand, gravel and hard pan are the best, for they are firm and can easily be drained. Trenches through earth and clay should have layers of sand and gravel rammed in solid to fill the whole width of trench from side to side. Soft strata overlaid with a layer of hard material, 6 to 8 ft. thick, is usually safe.

The footings must be far enough under ground to be below the reach of frost, and should go down to the original bed below any recent filling.

The cost of excavation without shoring will be about as follows:

General excavation in soft material, costs 25 to 50 cents per cubic yard.
Trench excavation in soft material, costs 50 to 100 cents per cubic yard.
Trench excavation in rock material, costs $1.00 to $2.00 per cubic yard.

Foundation Walls.—Brick should be clean and wet before laying, and basement walls should receive two coats of tar on the exterior before filling earth in behind them. Continuous walls are frequently the best, especially when columns are fairly close together, but separate piers are cheaper when they are far apart.

Piers.—Interior columns may be arranged to deliver their loads (1) on a solid slab of concrete covering the whole shop basement, (2) on separate concrete bases extending over to the adjoining wall columns, or (3) on independent interior piers. The first of these methods was used in 1886 in a New England mill 50 by 80 ft. in plan, a solid mass of concrete 3 ft. thick being placed under the whole building, but a more modern and improved method is shown in Fig. 80.

Individual piers should have several offset footing courses (Fig. 81) rather than building them as truncated concrete cones (Fig. 82), for in the first method the forms are more easily made. The projecting courses should be small enough so they will not crack, and successive layers should generally spread out at an angle not exceeding 30 degrees with the vertical. Spread concrete footings can also be made in octagonal form with plain or roughened reinforcing bars in four directions. Bars may gener-

ally be ½ to ¾ in. diameter, and 3 to 12 in. apart. Other bases may be made with beams or track rails in two directions, embedded in concrete, or timber foundations can be used in places where they will be always wet or always dry. When

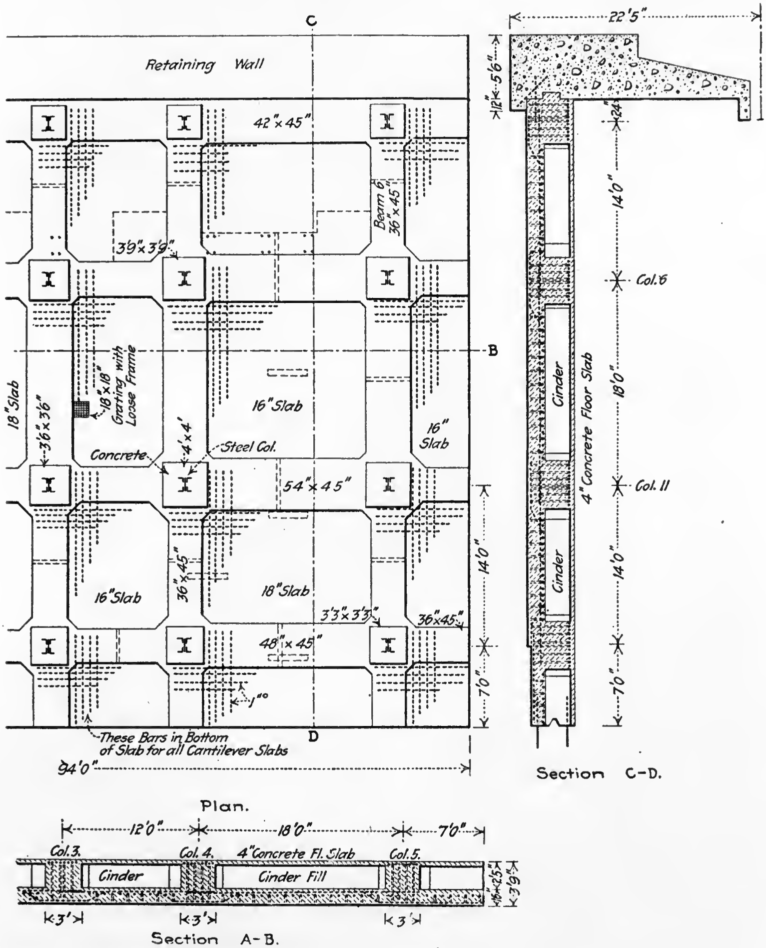


FIG. 80.—Foundation slab for a building over quicksand.

stone is used in piers, it must lie flat on its natural bed, but on account of their better bond, hard bricks or concrete are preferable. Piers should be large enough so the pressure on them will not exceed 250 lb. per square inch on stone, or 150 to 200

lb. on brick, and they should be capped with a block of cut stone, fine moulded concrete, or cast iron. The thickness of masonry caps should not be less than one-fifth of their longest side.

Notwithstanding general rules, each case must have separate thought and study, for it may need some special treatment.

Piles.—Bearing piles may be either of wood or concrete, and sheet piles of wood or steel.

The top of wooden piles should always be under water to prevent decay, because timber rots when alternately wet and dry. They should generally be driven until the penetration under the last blow of a 2000-lb. hammer does not exceed 1 in., though this is not an absolute rule, for in certain places as along the river at Buffalo, ground is so soft as to shake for 100 ft. in every direction when the hammer falls.

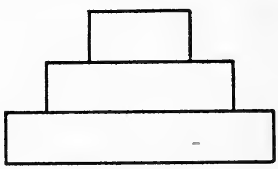


FIG. 81.

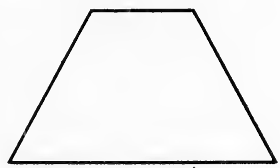


FIG. 82.

Saunder's rule for the safe load on piles is,

$$\text{Safe load, in pounds,} = \frac{3H}{2}\,\frac{W}{S}$$

while another and more recent formula is,

$$\text{Safe load, in pounds,} = \frac{2WH}{S+1}$$

In both of the above, W is the weight of hammer in pounds
H is the fall of the hammer in feet, and
S is the penetration in inches under the last blow.

Piles depending on friction will generally safely support 10 to 15 tons each, though never more than 25 tons. They should have an iron ring fitted over their head when there is a tendency to split, and they may also have pointed cast-iron shoes when necessary, though this adds to the expense and is often no better than pointing the pile itself. They can be driven $2\frac{1}{2}$ to 3 ft. apart, and when sawed off level, they should be capped with timber grillage or a solid slab of concrete 2 to 3 ft. thick extending down over the pile heads. Wooden piles usually cost 25 to 35 cents per lineal foot in place.

Concrete piles, because of their greater permanence, are coming into favor more than wood. They are made in several ways, each of which is patented. The average cost of concrete piles in place is $1 to $1.25 per lineal foot.

Sheet piling (Fig. 83) is plank connected with tongue and groove, or splines, and it can best be driven by light and rapid blows, for the wood is then less likely to split. Coffer dams consist of two rows of sheet piling 3 to 5 ft. apart, filled in between with clay puddle. To prevent overturning, the width between the inner and outer row of sheeting must be proportioned to the depth of water in which it stands.

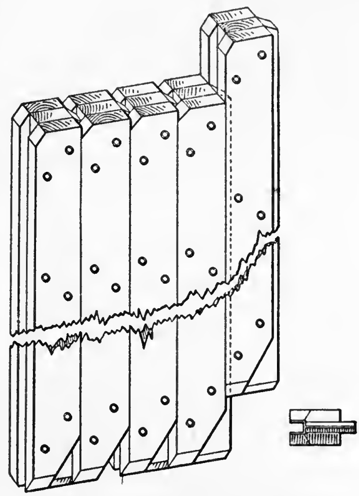


Fig. 83.—Detail of sheet-piling.

Engine Foundations.—Light machinery even when founded on masonry, will run smoother when bolstered up on timber. Masonry foundations should be laid in cement mortar. Those under steam hammers must have some spring and in this case solid timber is preferable to masonry, though a cushion of asphalt will assist in destroying vibration. The anvil foundation directly under the hammer should be separate and disconnected from that which supports the bearings at either side, so the impact from the blows will be transmitted directly to the earth, without jarring the other bases.

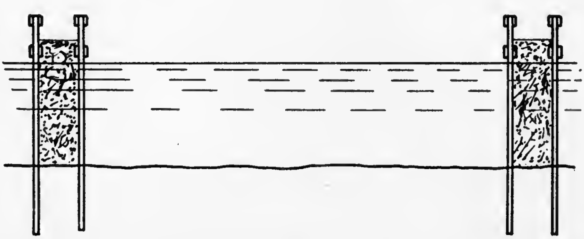


Fig. 84.

CHAPTER XIII

GROUND FLOORS [1]

Factory floors may be divided into two general classes, ground floors, and upper floors, and in each case a distinction must be made between the structural parts, and the wearing surface or finish. The various kinds of floors will first be described in order, after which will be given the types which are best suited for different shops and industries, the choice depending in each case upon the character of work done, and the size and weight of products and machinery. Wood, asphalt, clay, brick, concrete, and metal, are all suitable in their places, and they will be described in detail in later pages. In some buildings such as forge shops, a dirt or cinder floor is the best, while only a hard and dustless surface is suitable in rooms where fine instruments are made.

Ground floors should be built like good street pavements, being extra solid for heavy work and loads, and less permanent for lighter service. The common forms are: (1) earth, (2) wood block, (3) plank floors, (4) tar-concrete and wood, (5) cement-concrete and granolithic, (6) asphalt, and (7) brick.

Shop floors should generally have a slight grade, preferably in the direction of the greatest travel, not only to facilitate drainage, but also to make easier the starting and movement of loaded trucks and cars. Where water is freely used, as in car sheds and round houses, good drainage is imperative, for the best work cannot be done when men are standing in water with their feet wet. In the construction of steel frame buildings, the contract for which is frequently placed with a structural steel company in a distant city, the ground floor can usually be more cheaply made by a builder who is familiar with local conditions and the source of supplies.

Earth Floors.—These are perhaps the simplest kind of shop floors. There should first be laid a bed of sand, over which cinders are spread, and this should be well compressed and flooded with a hose every day for two or three weeks, being rolled each time after wetting. Instead of cinders, a mixture composed of

[1] H. G. Tyrrell, in *Engineering Magazine*, July–August, 1912.

one part of clay with three of gravel may be used, spread 8 to 12 in. deep and rammed, the clay acting as a cement or binder for the gravel. In any case, the floor must have a top layer of fine cinders or sand to prevent mud from forming on the surface.

Wood Block Floors.—Wood blocks make an excellent shop floor—one that is easy to walk upon, with little or no liability to slipping. When not subject to moisture or water soaking, the blocks can be used in their natural condition, and they must then be laid with 1/4-in. open joints for expansion, the joints being filled in with sand. When exposed to weather, the blocks should be creosoted and the joints filled with sand and pitch or cement grout. The flour should then endure for ten to twenty years.

A good specification for a wood block floor is to first spread and thoroughly compact a layer of gravel or cinders 12 in. deep over which is laid 4 in. of concrete. One or two inches of sand is then spread and rolled, and on this are placed the wood blocks. A modification of this floor was used in a large shop, 330 ft. wide and 776 ft. long, for the American Bridge Company at Ambridge, Pa. The slag base was first spread and rolled, and on this was placed a 6-in. layer of tarred gravel covered with 1 in. of tarred sand. On this were set the maple and beech paving blocks, which were 4 by 4 in., 8 in. long, the grain of the wood being vertical.

Instead of the concrete base above described, a 2-in. layer of sand is sometimes spread over the bottom course of gravel or cinders, and 2-in. plank laid thereon, as a base for the wood blocks. This latter method has the disadvantage that the plank distributes vibrations, and as the plank decays, a larger area must be removed for renewing or replacing it. This type of floor, with oak blocks 5 in. high and 6 to 12 in. long, was used in the car shops for the Illinois Central Railway Company at Chicago. The base of 2 by 12 in. hemlock planks was laid on sleepers embedded in sand.

Wood blocks may be used also for upper floors by placing under them two layers of paper laid in pitch, and joining the blocks with paving pitch and sand. This floor is suitable also in foundries excepting within a few feet of the ovens.

Plank Floors.—Wood floors are the most comfortable to walk and work upon, and are usually the best excepting in places where they would be destroyed by chemicals, moisture or heat.

The comfort of employees in working on wood floors is important and worth considering, for men can do their best work only when contented and comfortable. The preference of workmen in this respect is shown by the replies received from forty different factories, from twenty-six of which a decided choice was expressed for wood over any other kind of wearing surface. Pine flooring is perhaps the best when the life has not all been tapped out of the tree before sawing it into boards. Flooring boards for upper surface should not exceed 3 to 4 in. in width, and they should have hollow backs and be laid in the direction of the greatest travel. Seven-eighth-inch flooring is quite as good as one and one-eighth, for when the thinner boards are worn away enough for renewal, it would also be time to replace the thicker one. Maple wearing surface in short lengths is satisfactory, for it can be easily repaired. Two layers of tar paper should be placed between the upper and lower courses. The lower course should preferably span two bays or panels for the sake of greater strength or stiffness. Planks 3 in. thick or more should have splines rather than tongue and groove, though when floors are used for trucking, the upper boards should have square edges, as grooved edges break under heavy loads and wheels. Blind or edge nailing interferes with repairs and is, therefore, not desirable. Four-inch planks should have 7-in. steel spikes, one keg of 100 lb. being enough to lay 1200 sq. ft. of floor.

All wood floors have the disadvantage that water used in cleaning them will soak into the cracks and cause the boards to expand and form ridges. It is important, therefore, to devise methods for preserving them, one good process being that of creosoting. In this process, the wood is first dried and the creosote oil is then forced into it under a pressure of 150 lb. per square inch. Unseasoned timber must remain unpainted, for paint on such material is worse than none at all. After two or three years, when the wood is dry, it should receive three coats of oil paint. The timber must also be well ventilated to prevent destruction from dry rot.

A very cheap and temporary floor ismade by placing 3-in. plank on half-round timbers, 3 ft. apart, embedded in 6 to 8 in. of cinders, the wood being coated on the under side with lime. Its cost is very low, being only 50 cents per square yard. A floor similar to this with 2-in. plank on chestnut slabs, embedded in

gravel over made ground, decayed within a year, and, thereafter, about half of it was replaced annually. In the immediate vicinity was another floor with 2-in. plank on 3 by 12-in. joists, supported on 12 by 12-in. sills and masonry piers, which required no renewal for twelve years. A floor similar to those described above, with sills embedded in sand instead of cinders, was used twenty-five years ago in a shop for William Sellers and Company, of Philadelphia, an effort being made to preserve the plank by placing under it a layer of resin $\frac{1}{4}$ in. thick.

Three other temporary wooden floors may be mentioned; the first has $\frac{7}{8}$-in. flooring over 2-in. plank with sleepers embedded in gravel; the second has 4-in. plank on sills laid in broken stone; and the third, 3-in. plank on 4 by 6-in. sills, 4 ft. apart, embedded in about 6 in. of cinders. These have the advantage of low cost, the last costing not over 10 to 12 cents per square foot, with lumber at $30 per thousand, board measure. If a concrete base is used instead of cinders, the cost would be 25 to 30 cents per square foot.

A floor heavy enough to carry ordinary machinery anywhere without special foundations is made by first laying and ramming an 8-in. concrete base, after which 6 by 6-in. timbers are placed 3 to 4 ft. apart, and the space between them filled with concrete, after which a 3 in. floor was laid. A still heavier floor of the same kind with a solid layer of concrete, 2 ft. thick, covered with plank on sleepers, will permit heavy machines to be set anywhere without special foundations. Such a floor was used in the erecting shop of the Allis-Chalmers plant, at Milwaukee, Wis.

A similar but lighter floor with 2-in. maple wearing surface and 1 by $\frac{1}{4}$-in. splines, was used in the Santa Fé Railway shops, the maple flooring being spiked to 3 by 4-in. yellow pine sleepers 18 in. apart, embedded in 6 in. of concrete. In this case the concrete and sleepers without the flooring cost 8 to 9 cents per square foot. In the McKees Rocks railroad shops, wire conduits were placed below the floor at intervals of $5\frac{1}{2}$ ft., for receiving the light and power wires for the machines. A layer of concrete 4 in. thick was first spread and covered with five sheets of tarred felt in hot tar, over which was spread an inch of sand. On this layer of sand, 4 by 4-in. sleepers were laid and filled between with more sand, over which was spiked a course of $2\frac{3}{4}$-in. pine plank, and a wearing surface of $1\frac{1}{8}$-in. tongue and groove maple. The railway shops at Parsons, Kan.,

have a somewhat similar floor excepting that the wearing surface is 4 by $1\frac{1}{4}$-in. white oak with a layer of roofing felt between the upper and lower courses. The 3 by 4-in. yellow pine sleepers were treated by the zinc process to preserve them, and the space between them filled with dry sand. They were laid on an inch of sand and tar over a 6-in. bed of broken stone. Floors of this general type with slight modifications are numerous, showing the favor with which they are received.

One man will lay $2\frac{1}{2}$ squares (250 sq. ft.) per day of eight hours on upper floors including the hoisting, and three squares per day at street level. Laying sleepers costs \$4 to \$4.50 per thousand feet, board measure, and 3-in. flooring about \$3 per thousand.

No. 1, Y.P. 2×6-in. tongue and groove, costs \$8 to \$10 per square laid.
No. 1, Y.P. 3×6-in., tongue and groove, costs \$13 per square laid.
$4\times\frac{7}{8}$-in. Y.P. tongue and groove, costs \$7 to \$8 per square laid.
$6\times\frac{7}{8}$-in. Y.P., tongue and groove, costs \$5 to \$6 per square laid.
$4\times\frac{7}{8}$-in. W.P., tongue and groove, costs \$8.50 to \$10 per square laid.
$2\frac{1}{4}\times\frac{13}{16}$-in. clear maple, tongue and groove, costs \$11 to \$13 per square laid.

Floors of Tar-concrete and Wood.—An excellent shop floor consists of a base of concrete and tar or asphalt, with a wood wearing surface. Over a mixture of tar, the wood is preserved, while over cement concrete it decays quickly, and over dead air space, it succumbs to dry rot. A floor of concrete and tar with wood top is solid, without vibrations, tools do not break when they fall, and machines may be screwed to the floor anywhere. It is nearly fireproof because there are no sleepers and no air space beneath the wood. It is not expensive, and will last from twenty to twenty-five years, while the wood top makes it comfortable to walk upon. It is laid by first spreading a 4-in. layer of screened gravel or stone not larger than $2\frac{1}{2}$ in., mixed with tar. The tar should be heated to 200° F., and enough added so the mixture will be compact when rolled, the amount of tar required for different kinds of aggregate being as follows:

Stone $2\frac{1}{2}$ in. to 1 in. diam. use.......	6 gallons of tar per cubic yard
Stone $2\frac{1}{2}$ in. to $\frac{1}{4}$ in. diam. use.......	9 gallons of tar per cubic yard
Coarse gravel.......................	7 gallons of tar per cubic yard
Fine gravel........................	10 gallons of tar per cubic yard

The sand and gravel should be well heated before the tar is added. Over hard ground, 2 or 3 in. of tarred stone may be

enough. No economy results from using cinders or sand in preference to stone for the bottom covering, for cinders require 15 gallons of tar per cubic yard, and sand, 20 gallons. Stone at $1.25 per cubic yard has, therefore, no greater ultimate cost than cinders at 50 cents per yard. In some cases, 4 to 6 in. of cement concrete is used for a base course, instead of the tar-concrete above specified, but when this is done, it should receive a coat of tar before laying the sand. Over this base of concrete is spread a 1-in. layer of sand and tar, mixed in the proportion of 50 to 60 gallons of tar to each yard of sand. This mixture should be heated to 225° F., spread 1¼ in. thick and rolled down to 1 in. While it is yet warm and soft, a layer of 3-in. plank is embedded therein, over which is laid a top wearing surface of maple.

The cost of a floor made of cinders and tar 6-in. deep, overlaid with 3-in. plank on 3 by 4-in. sleepers, 16 in. on centers, embedded on the cinders, is as follows:

Cinders and tar...............	8 cents per square foot
Wood.......................	16 cents per square foot

In the above, one barrel of tar was used with eight barrels of cinders. With tar at $2 to $5 per barrel, the cost of these floors should not exceed 24 to 30 cents per square foot. A floor of this kind in a shop for the Boston and Albany Railroad Company, with a 4-in. layer of coal-tar-concrete, overlaid with one inch sand and ¼-in. roofing pitch, with two layers of spruce plank, 2½ and 1½ in. thick, cost in 1898 only 18 cents per square foot. Without the wood work, the cost of base with stone, sand and tar should not exceed 10 to 13 cents per square foot.

This type of floor has been used with many modifications. In one shop cement concrete was laid 6 to 12 in. thick, with 4 by 4-in. wood strips embedded therein 2 ft. apart. Over the strips and concrete, was spread a layer of fine sand and coal tar, in which the lower plank course of 2-in. tongue and groove yellow pine was laid and nailed. The wearing surface in this case was 4 by 1⅛-in. maple with square edge. Owing to the splitting of matched flooring under trucks, and the difficulty of repairing it, square edge boards are frequently preferred for the upper course.

Cement-concrete Floors.—Floors of cement-concrete should be laid similar to a good sidewalk pavement, with cement and

aggregate mixed in about the same proportion. In determining the proportion of materials for the aggregate, a barrel should be filled with broken stone, or the largest material, and the amount of water that can be added to the barrel thus filled, represents the amount of gravel or fine-crushed stone that it will hold. This amount of gravel and crushed stone should then be placed in another barrel, and the amount of water that can be added without increasing its bulk represents the amount of sand needed. In the same way, the required amount of sand should be placed in another vessel, and the amount of water that it can be made to hold will represent the required amount of cement. In order to have all voids in the larger material well filled by the finer ones, it is well in each case to increase the amount of finer material by about 25 per cent. over the theoretical amounts found by the above tests.

For making these experiments, it may be more convenient to use a box of exactly one or two cubic feet capacity, and the proportion by weight may be determined by weighing the ingredients as found from the above experiments. To obtain the proper density for a water tight floor, the proportion of cement should generally be not less than 1 part of cement with 2½ of sand and 4½ of larger aggregate, though in some cases a tight floor has been made with a leaner mixture at a proportionately less cost. Unscreened material from a sand and gravel bed are sometimes used, but as their relative amounts are uncertain, it is usually better to mix them in definite known proportions.

One barrel of cement contains 3.8 cu. ft., and when mixed as directed above, the concrete will cover an area of 100 sq. ft., 2½ in. deep.

The depth of excavation and filling under the concrete will depend on the nature of the subsoil and local condition, as well as on the carrying capacity of the floor, a wet soil requiring a greater depth of broken stone for drainage. A heavy floor may be strong enough to support large machines placed anywhere, while a lighter one may require special machine foundations. As a general guide for laying concrete floors, the following directions are given. First, excavate the soil to a depth of 15 to 22 in. below the finished grade level. Then spread a layer of broken stone 8 to 12 in deep, over which lay 4 to 6 in. of gravel or crushed stone, thoroughly tamped and rolled. Then spread a layer of concrete 2 to 4 in. thick which must be covered while it is still

green with a wearing surface ½ to 2 in. thick (1 in. being the usual) composed of cement and sand in the proportion of 1 to 1, or 1 to 2. It may be colored if desired, and should be leveled off with a straight edge and marked into squares or rectangles. Shrinkage cracks will then follow regular lines instead of making irregular breaks through the pavement. The mixture for the wearing surface, should be thin enough so that, when laid and troweled off, the cement will come to the top and form a hard smooth surface when dry. It is important that the lower course be green or mcist when the weaiing surface is applied, for if dry, the upper course will soon crack and disintegrate. The floor should be protected for about thirty-six hours, after which it is ready for use.

Instead of using 12 to 18 in. of broken stone and gravel as specified above, a depth of 5 to 6 in. may be enough in some cases for light floors and well drained subsoil, the cost of this lighter construction being 12 to 20 cents per square foot. A concrete slab 6 in. thick with ½-in. surface finish, supported on a well-drained base of gravel or broken stone, has been found satisfactory for round houses, though somewhat difficult to repair.

The cost of a floor with ½-in. surface over a 2-in. concrete base, is as follows:

Cement	30 cents per square yard
Stone and sand	10 cents per square yard
Labor	26 cents per square yard
Total	66 cents per square yard

In the above, the labor cost of surface finish is 14 to 15 cents per square yard, and for a greater thickness of concrete base, the cost would be increased 18 cents per square yard for each additional inch of thickness. A light floor with 1-in. wearing surface and concrete only 4 in. thick, can be laid at the rate of 100 sq. ft. per day of eight hours for each man employed, the cost per square foot being

Materials	9 cents per square foot
Labor	2 cents per square foot.
Total	11 cents per square foot

Assuming sand and gravel to cost $1 to $1.25 per cubic yard, and crushed limestone, $1.50 to $1.75 per cubic yard, the cost

of concrete may be taken at 20 to 25 cents per cubic foot, and a 1-in. surface finish at 5 to 6 cents per square foot. A 1-in. finish over a 6-in. concrete base should, therefore, cost 15 to 18 cents per square foot. A cement base 10 in. high and $\frac{5}{8}$ in. thick joining the wall and floor, costs 12 cents per lineal foot in place in large amounts, and 15 to 20 cents per lineal foot for smaller quantities, and the labor cost of forming floor gutters is 15 to 20 cents per lineal foot. When this type of floor is used in a foundry, the finished wearing surface must be covered with 4 in. of moulding sand.

Granolithic Floors.—Granolithic floors in shops are not very popular and yet as they are largely used, some rules are given to aid in securing the best results. In order to discover the degree of favor with which they have been received, letters were sent a year or two ago to a large number of factory owners, and out of forty replies received, twenty-six expressed a decided preference for wood, with only eight in favor of granolithic, while the remaining six liked the two kinds of floor equally well. As the chief objection to granolithic floors is that they rapidly convey heat away from the body and produce a feeling of weariness, it is now an established rule that these floors are suitable only when they are heated. This has been successfully done in several shops, as in the plants of the Brown Hoisting Machinery Company and the Morse Chain Company. When these floors are not heated, employees may wear shoes with wooden soles, as is frequently done at metallurgical works when walking over hot metal, or where the floors are constantly wet.

Some other disadvantages of granolithic floors are that they are dusty and wear into ruts and hollows, especially when exposed to the action of trucks and wheels. The tendency to dusting or to disintegration of the surface is due to a lack of density, and can be avoided by attending to the directions for laying granolithic herein given. When laid out in squares or rectangles the granolithic chips around the edges, and for this reason wheels should have rounded treads or rubber tires. Concrete is also chipped by heat, and in conflagrations it disintegrates for a depth of about half an inch below the surface.

Granolithic floors need experienced men to lay them, for it only requires a little bad workmanship, poor concrete, insufficient cement, or some foreign substance such as loam, to make the floor a failure, and early breaks and disintegration a certainty.

They are also difficult to repair, much more so than wood, and repairs occupy a longer time. They are not suitable for shops with edged tools, which are easily injured, and castings are liable to break by falling. In addition to these objections, it is difficult to attach machinery to granolithic floors.

The merits of these floors depend largely upon the care with which they are laid. They are fireproof, and are accepted as waterproof by the New York Board of Fire Underwriters. They can be washed off clean without injury and are not disintegrated by such usage. When properly laid, they are impervious to oil and are not injured by it, though oil will, of course, enter cracks which are large enough to admit it. These floors are cheaper than wood and when heated, as can easily be affected in upper stories, they no longer have the objection of causing cold feet and limbs.

The most approved mixture for granolithic work consists of equal parts of cement, sand, and screened crushed stone, from a size which will pass through a 20-mesh up to a maximum size of $\frac{1}{2}$ in. It is important that the crushed stone be screened to remove the dust. Some cement users prefer to omit the sand entirely, using only equal parts of cement and screened crushed stone. It should be mixed as dry as can be worked, and put down in two layers with a total thickness of about $\frac{3}{4}$ in., the top coat being put on while the under one is wet, so they will unite. To prevent edge chipping and dust formation, the squares should be large, not less than about 20 ft., and where the floors are to be used by horses for pulling loads, the surface should be roughened. Along heavy lines of travel, wheel plates of either wrought or cast iron may be set into the floor, or a track may be made of iron grating bars on edge, filled in between with the granolithic mixture. These will prevent the floor from cracking and supply horses with a good foothold. A recent and rapid method of surfacing concrete floors is by the use of the cement gun worked by compressed air which throws the mixture into place through a hose. It has been successfully used by the United States Government and is proposed for some large buildings in Chicago.

Dust formation may be avoided in several ways, the easiest of which is to give the surface a hard troweled finish. Dust may also be prevented by an occasional application of hot silicate of soda, or a wash of linseed oil thinned with turpentine or naphtha,

or by painting. A method of preventing dust which is perhaps the most effective of all, is to cover the floor with linoleum fastened down with glue, using $1\frac{1}{2}$ gallons of glue per 100 sq. ft. of floor surface.

Granolithic $1\frac{1}{4}$ in. thick, when laid on a moist or green base, costs $4\frac{1}{2}$ cents per square foot, but when put down after the base has hardened, it will cost about 7 cents.

The repairing of these floors is also important, requiring the services of skilled workmen. Main aisles or passageways, when they become worn, may be reinforced with an additional layer of granolithic over the old one. Broken edges may be repaired with a mixture of soft asphalt, the bonding being affected by heating the injured surface with a blow torch. This method is better than patching with cement paste, though not as permanent as the process described later. The most approved method of repairing is to cut away the granolithic with a sand blast or with chisels to the bottom of the break, until the aggregate is exposed enough to give a bond. Then treat the surface with acids and wash with a hose to remove the dust, after which, the surface should be covered with a thin grout. The new granolithic material should then be applied while the grout is still wet, and the patch should be kept protected and moist for about a week, when the repaired floor is again ready for use.

Asphalt Floors.—Asphalt floors have many commendable features, though costing more than some other kinds. They are waterproof; have no dust; are not volatile like tar; are elastic enough to prevent crack formation; can be kept clean; and are comfortable to walk upon. They do not tire the feet of workmen like concrete or brick and do not wear away but simply compress. They are not injured by frost or thaws, and should last at least ten years without repairs.

Rock asphalt is limestone impregnated with 8 to 17 per cent. bitumen. It is made into asphalt mastic for commercial use, by first grinding it to a powder and then heating it for five hours in a kettle at a temperature of 350° F. with 8 per cent. of Trinidad asphalt added to prevent its burning. It is then moulded into blocks weighing 50 to 60 lb., each block having the name of the mine moulded thereon. The finished product contains 14 per cent. of bitumen and 86 per cent. carbonate of lime.

It is prepared for floors by mixing it with Trinidad asphalt and sand in the following proportions by weight:

Broken mastic blocks	60 per cent.
Trinidad asphalt	4 per cent.
Fine gravel and sand	36 per cent.
Total	100 per cent.

The mixture is then heated to a temperature of 300 to 400° F. for about five hours and constantly stirred, after which the mixture is taken out and spread on the floor to a thickness of 1 in. It is then covered with sand and rubbed to a smooth finish. A base for this floor may consist of a layer of concrete 3 to 4 in. thick, or a course of plank on sleepers, the plank being overlaid with tarred felt or sheathing paper. Asphalt is also moulded into paving blocks 4 by 4 by 12 in., and when laid with these blocks, floors are more easily repaired.

Asphalt has several imitations made of tar and crushed limestone which are of poor quality, for like other tar products, the tar evaporates and the floor cracks. Asphalt floors are not suitable in shops where oil collects or drips, for the asphalt is softened and destroyed by oil. A 1-in. floor without the base costs from 16 to 18 cents per square foot.

A substitute for asphalt paving which may be suitable also for shop floors is now extensively used on streets at Ann Arbor, and is giving good service. Over a base of 4 to 6 in. of gravel-concrete, tar or bitumen is spread, using a half gallon per square yard, and into this is rolled a layer of sand ¼ in. thick. The wearing surface complete, costs only 5 cents per square yard, and the whole pavement about 80 cents per square yard, with labor at $2 per day and cement at $1 per barrel.

Brick Floors.—A fine basement floor over dry soil is made by first placing a 12-in. layer of well compacted sand rolled and leveled, over which a course of brick is laid flat, and on this another layer of brick on edge, both courses being jointed with cement mortar and grouted full.

The floors of foundry pits should have two layers of brick over a 6-in. concrete base, and the pit walls should be one brick, or 8 in. thick, all laid in cement mortar. For boiler house floors, the bricks may be laid flat with diagonal joints, giving a pattern effect. There is no better floor for round houses than brick, for when injured they are easily repaired. The pressure of heavy jacks and the rolling about of trucks and wheels have been found to cause frequent breakage to round house floors; and when made of brick, they can be easily replaced by removing only a small

portion. Wood floors wear out too quickly, and concrete cracks and disintegrates under heavy loads. A timber base should be avoided, the repairing of which would necessitate the removal of a larger area.

The ground should be excavated to a depth of 8 in. and should then be well rammed, all alluvial soil being removed and depressions filled up with sand and gravel. A 4-in. layer of sand should then be spread and tamped, after which hard bricks are laid on edge. If a waterproof floor is needed, the bricks should be grouted and covered with tar. As slag and cinder usually costs the railroad company nothing, they are frequently used as a bed for these pavements instead of sand and gravel. The floors of engine pits should be crowned two inches at the center for drainage, and the walls should be capped with timber at each side of the pit. These floors usually cost from 85 cents to $1.15 per square yard.

Recommended Types.—The types of floor which have been found from experience to be the best for shops of different kinds are given in the following tabulation:

Annealing rooms	Brick or cast-iron plates.
Car shops and car houses	Concrete base with granolithic finish.
Cleaning rooms	Cast-iron plates.
Cupola floors	Inverted steel channels, rough rolled or cast-iron plates.
Forge shops	Earth or cinder floors.
Foundry pouring floors	Cast-iron plates or brick on plank and sand.
Moulding floors	Concrete or brick.
Machine shops	Creosoted wood blocks or plank on concrete base.
Offices	Maple or yellow pine on sleepers over concrete.
Power house, Engine rooms	Concrete with cement or tile finish.
Power house, Boiler rooms	Concrete with cement or brick on edge.
Toilets	Concrete with cement finish.
Wash rooms	Concrete with cement surface.

The above are generally the best, though in some cases, such as round houses and machine shops, preference and practice has a considerable variation. Round house floors have received much attention from the railroad companies, and several types are extensively used, including cinders on clay, plank, brick, and concrete. These floors receive very hard usage from hydraulic jacks and the removal of trucks and other parts, and a floor of

vitrified paving brick is usually preferred; for as previously stated, when damaged, it can easily be repaired by removing only the injured part. The repairing of timber or concrete floors is more difficult, for a larger area must be taken up. Wood blocks lack resistance, and when laid over planks, they are subject to the same objection as other timber floors.

Machine shop floors have been the subject of many experiments. They usually receive hard service, especially in erecting shops where loads are dragged along the floor by the lifting cranes and machinery parts are piled up high, thus subjecting the floors to heavy weight. Brick, concrete and asphalt conduct heat away from human bodies and are, therefore, uncomfortable; and sharp-edged tools are injured by falling on such hard surfaces. Grit and dust rising from them are injurious to machines, especially in the bearings. For these reasons, some kind of wood floor is usually preferred.

CHAPTER XIV

UPPER FLOORS

Slow Burning Wood Floors.—The essential principle of this type of construction is to use the fewest number of large framing pieces, so that they may not easily be attacked by fire. It has been well proven by numerous fires that wood framing so arranged is a better fire risk than unprotected steel framing, which collapses quickly under heat.

Beams should not be closer than 5 to 10 ft. apart, and the proper spacing may be found from the following table giving the required thickness of plank for various spans and loads.

TABLE XV.—SAFE LOADS IN POUNDS PER SQUARE FOOT FOR SPRUCE PLANK OF VARIOUS SPANS AND THICKNESSES, FOR LIMITED DEFLECTIONS

Load per square foot superficial	Span in feet										
	4	5	6	7	8	9	10	11	12	13	14
30	0.9	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.8	3.1	3.4
40	1.1	1.4	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.5	3.8
50	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2
75	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	5.0	5.4
100	1.7	2.2	2.6	3.0	3.4	3.9	4.4	4.8	5.1	5.6	6.0
125	1.9	2.4	2.9	3.4	3.8	4.3	4.8	5.3	5.7	....	....
150	2.1	2.6	3.1	3.7	4.2	4.7	5.2	5.7	....	....	....
175	2.3	2.9	3.4	4.0	4.5	5.2	5.8	....	....	....	....
200	2.4	3.0	3.6	4.2	4.8	5.4	6.0	....	....	....	....
225	2.5	3.1	3.8	4.4	5.1	5.6	....	....	....	....	....
250	2.7	3.3	4.0	4.7	5.4	6.0	....	....	....	....	....
275	2.8	3.5	4.2	4.9	5.6	....	....	....	....	....	....
300	2.9	3.6	4.4	5.2	5.9	....	....	....	....	....	....
325	3.1	3.8	4.6	5.4	6.1	....	....	....	....	....	....
350	3.2	4.0	4.8	5.6	....	....	....	....	....	....	....
375	3.3	4.2	5.0	5.8	....	....	....	....	....	....	....
400	3.4	4.3	5.1	6.0	....	....	....	....	....	....	....

Plank when laid flat, should, for thicknesses of $2\frac{3}{4}$ in. or less have tongue and groove, and for greater thicknesses should for economy be connected by splines. An excellent solid floor is obtained by placing boards on edge, and spiking them together,

the upper surface being covered with 1/2-in. tar mortar before laying the top course of boards.

The mortar should consist of one part of tar with two parts of sand. The extra strength of continuity is secured by staggering the board joints, preferably at the point of contra flexure, about one quarter way between the bearings. The best material for wood beams is hard or yellow pine. The lower corners should be champfered, and in brick walls, beams should have cast-iron bearing plates with flanges, one to anchor them to the masonry, and another fitted into the beam. The upper end of the beams above the bearings should be mitred, to prevent inner leverage on the wall, in case the beams collapse by fire.

Wood floors should always have an upper wearing surface which can be removed as often as it becomes worn. Yellow pine is the best, though maple and oak are sometimes used. The edges were formerly matched or tongue and grooved, but owing to the difficulty of replacing this kind of floor, and its liability to splitting at the edge under trucks or other loads, square-edged flooring is now preferred. A thickness of $\frac{7}{8}$ in. is quite as good as $1\frac{1}{8}$ in., for when the floor is worn enough to need renewal of the thinner boards, the thicker board would also have needed renewal.

In order to prevent water from leaking through the floor, there should be two or three layers of tar or rosin paper between the upper and lower courses, and the last layer of paper should preferably be mopped with tar. Asbestos paper for this purpose has the additional advantage of being fireproof. Wood must remain unpainted until the timber is thoroughly seasoned, for if applied too soon, it only promotes decay.

The cost of wood floors with $\frac{7}{8}$-in. maple over 3-in. plank on 8 by 12-in. yellow pine, 6 ft. apart, is as follows:

Wood beams	$ 6.50 per square
Iron stirrups	3.00 per square
Anchors	2.50 per square
3-in. plank	12.00 per square
Paper	.50 per square
Factory maple flooring	7.00 per square
Total	$31.50 per square

The Sessions Foundry at Bristol, Conn. has 3-in. tongue and groove yellow pine on 12 by 18-in. yellow pine beams, while a

gallery floor in the Granger Foundry at Providence, designed by the writer, has a double wood floor on 8 by 12-in. beams only 5 ft. apart, supported on 12-in. steel beams.

These floors should be protected against fire by an adequate sprinkling system.

Wood Floors with Steel Beams.—A low cost wood floor which is lacking in fire resisting qualities, is made by placing heavy wood joists say 3 by 16 in., 16 to 20 in. apart—which are supported on steel beams or riveted girders 10 to 15 ft. on centers. The cost of wood work in the floor, with two layers of pine, $\frac{7}{8}$ and $2\frac{1}{2}$ in. is 12 to 15 cents per square foot erected, not including any steel.

As framing timber is becoming more scarce every year, steel joists are often used instead of wood, and this type is now accepted by the insurance companies as a substitute for slow burning wood construction. Beam spacing in this type can be reduced to 3 or 4 ft. with a corresponding reduction in the thickness of plank. The steel joists are capped with wood spiking pieces, about 4 by 5 in., which are hook bolted to the beams. The beams may be protected from fire by a suspended ceiling of expanded metal and plaster, and if extra fire precaution is needed, an upper wearing surface of asphalt may be used instead of wood. Suspended ceilings are only a partial protection, for in great conflagrations, such as at San Francisco, it was found that these ceilings break.

Triangular Sheet Steel Floor (Buckeye).—Several forms of sheet metal trough floors are available, most of them having the merit of maximum stiffness for the amount of material used. One of these, made in Ohio and known as the Buckeye floor, has metal trough $2\frac{1}{2}$ in. deep, and including the concrete filling and $1\frac{1}{2}$ in. wearing surface, weighs about 35 lb. per square foot.

WEIGHT OF GALVANIZED TRIANGULAR TROUGH FLOORING, $2\frac{1}{2}$ IN. DEEP, IN POUNDS PER 100 SQ. FT.

Gauge	
No. 16	386 lb. per square
18	313 lb. per square
20	241 lb. per square
22	204 lb. per square
24	168 lb. per square

The sheets are made in lengths up to 10 ft. and in uniform widths of 21 in.

Multiplex Floor.—Another excellent sheet metal trough floor is that known as the Multiplex. The troughs are made of 2 in. uniform width, and depth of 2, 2½, 3 and 4 in. either painted or galvanized. Stock lengths vary anywhere from 5 to 10 ft., and gauge from No. 16 to No. 24. They are laid directly on the floor beams and are filled with concrete to a depth of 2 in. above the metal, but cannot be plastered on the under side and must be kept painted. If a wood wearing surface is desired, wood nailing strips must be embedded in the concrete above the metal, or these may be omitted, and a granolithic surface used instead.

TABLE XVI.—SAFE LOADS ON MULTIPLEX STEEL FLOORS WITH CONCRETE FILLING 1 IN. ABOVE THE METAL

Metal gauge	Depth	Weight	4 ft.	6 ft.	8 ft.	10 ft.
20	4	18	1260	550	300	185
24		17.3	792	352	198	127
20	3½	17.5	1115	485	265	165
24		16	720	320	180	115
20	3	15.3	970	420	230	145
24		14.0	550	244	137	88
20	2½	13.4	675	295	160	100
24		12.2	433	192	108	69

Metal Arches.—Arches of stiffened sheet metal between steel beams with concrete filling above them, are extensively used. They have the objection common to all kinds of exposed metal, that they must be kept painted, or they will be destroyed by rust. No. 18 gauge corrugated iron with a 10-in. rise, between beams 6 ft. apart, has been tested with a load of 1000 lb. per square foot, and for beam spacing of 9 ft, with 3 in. of concrete over the metal at the center, it will safely carry a load of 200 lb. per square foot. The strength of this floor can be increased by making a greater crown thickness of concrete. It is, therefore, strong, apart from the filling above it, which, for the sake of lightness, is sometimes made of cinders. If cement and stone concrete is used instead of cinders, the strength is greatly in-

creased. A floor of this kind in an engine house designed by the writer cost 56 cents per square foot in place. Dovetailed metal is sometimes used instead of corrugated iron, with the false impression that it can safely be plastered on the under side. This product offers insufficient grip to hold plaster, for a large building in which it was thus used was inspected by the writer after the plaster had fallen. The fall of so much heavy material not only injured the machinery, and other contents of the building but also endangered the lives of the workmen. No. 24 gauge dovetailed sheets cost $8 to $10 per 100 sq. ft. at the place of manufacture, and weigh 163 lb.

Metal Trough Floors.—A much stronger and heavier metal floor is obtained by using troughs made of rolled shapes riveted together. These are more used for very heavy service as on bridge floors, but are occasionally appropriate in buildings, the office of the Pencoyd Iron Works, having several floors, made of Lindsay troughs painted a light blue on the under side. Floor sections made with sloping sides are liable to vary slightly in width when riveted, and it is, therefore, difficult to match the connecting holes in the supporting girders. For this reason, vertical sides are generally preferred. To economize in head room, the sections should rest on shelf angles, fastened to the girder webs rather than bearing on their upper flanges. Vertical troughs in small sizes are most conveniently made of Z's and plates, but for greater depths they are composed of plates and angles. Floor troughs vary in weight from 15 to 40 lb. per square foot, and tables of safe loads may be found in the handbook of the Carnegie Steel Company.

Plate Floors.—Cast-iron or rolled-steel plates roughened on the upper side are much used in certain places exposed to fire, such as cupola floors, or around furnace openings. Rolled steel plates are made in thicknesses of $\frac{5}{16}$ in. to $\frac{1}{2}$ in., weighing 13.8 to 21.4 lb. per square foot. Cast-iron plates can be made heavier and stiffer than rolled ones and can be roughened enough on the surface to prevent men from slipping. They are extensively used in foundries and for charging floors.

Brick Arch Floors.—Brick or terra cotta arch floors are heavy and expensive and not well suited to factory buildings subject to jars and vibrations. The movement of heavy machines is liable to loosen the bricks and cause them to fall Brick arches are laid in single rings 4 in. thick on temporary wooden forms,

the distance between beams not exceeding 4 to 5 ft., and the arch rise at least one-eighth of the span. The filling and floor above the arch may be similar to that used in other arch forms, and concrete may be used for filling, with a finish either of wood boards on nailing strips, or granolithic.

CHAPTER XV

CONCRETE UPPER FLOORS

Concrete floors are of three general kinds.

1. Those without slabs but with concrete beams and wood floors.

2. Those with concrete beams and slabs.

3. Those with flat concrete slabs only, supported directly on columns.

The first of these types with no slabs but with concrete beams supporting a double layer of floor planks (Fig. 79) is very economical in cost. It is also lighter than a concrete floor, for while this material weighs 140 lb. per cubic foot, wood does not exceed 50 lb. A four-story concrete office building in Massachusetts, with T-beams without slabs and two layers of wood floor, cost with the equipment of lighting, heating, toilets and partitions only 9.2 cents per cubic foot, or \$1.30 per square foot of floor area. Without equipment, the cost including foundation, walls, floors and roofs, was only 4½ cents per cubic foot, or \$0.63 per square foot of floor area. Wood nailing pieces were secured to each side of the concrete beams, and between it and the lower course of plank was a thin filling of cinders. A five-story concrete factory in the same state, 50 ft. wide and 300 ft. long, of the same general type as the last, cost without equipment, only 7.6 cents per cubic foot, with a total saving of \$24,000 over a concrete design with beams and slabs.

A floor of the same type in a knitting mill in the central part of New York state, cost:

2-in. hemlock plank	\$.07	per square foot
Deadening felt	.005	per square foot
7/8-in. floor and finish	.09	per square foot
Plaster board	.025	per square foot
Total	\$.19	per square foot

For the same place a floor with reinforced concrete slab and wood top, would have cost:

Reinforced concrete slab..................	$.40 per square foot
Nailing strips in place....................	.03 per square foot
Upper floor, finished.....................	09 per square foot
Plaster under.............................	.04 per square foot
Total....................................	$.56 per square foot

or about three times as much as that used.

Generally, concrete buildings with timber floors but without any slab, cost 15 to 25 per cent. less than when a slab is used, and they cost less than wood mill construction.

Floors with Beams and Slabs.—This type constitutes by far the

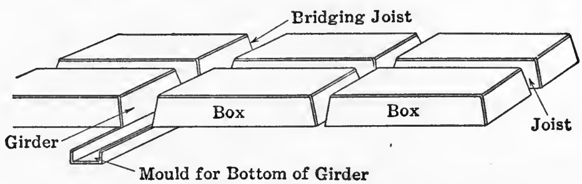


Fig. 85.—Metal covered, wood form boxes.

largest class of floors in concrete buildings. Apart from shop-made floor sections and joists, which have previously been described under "Separately Moulded Members" there are

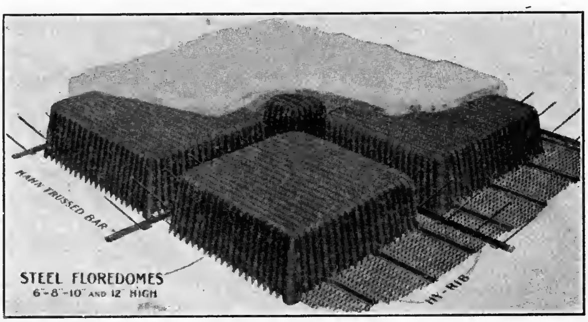


Fig. 85a.—Steel forms for concrete floors.

many systems of monolithic beam and slab construction. A type which is qute economical is that used in buildings for the University of Wisconsin. For the purpose of forming ribs, inverted boxes were used instead of the usual forms, and they were so arranged as to make a system of inverted beams and joists, Fig. 85. These boxes were covered with sheet metal and were used thirty times or more. The total floor area in one building was 4500 sq. ft., and provision was made for a live

load of 200 lb. per square foot. The itemized cost of floors in this building, per square foot of floor was as follows:

Concrete	10.54 cents per square foot
Reinforcing steel	7.86 cents per square foot
Timber for supports	6.60 cents per square foot
Wood boxes, 1/15 of cost	.72 cents per square foot
Erecting supports and boxes	5.54 cents per square foot
Placing concrete and reinforcement	4.44 cents per square foot
Removing supports and boxes	1.10 cents per square foot
Total	36.80 cents per square foot

A system of beams placed close together, with sloping sides, forming a heavy ribbed slab (Fig. 86), was used in the balcony floor of a machine shop for the Fairbank-Morse Company at Toronto, Canada. The beams were 22 in. wide at the top and

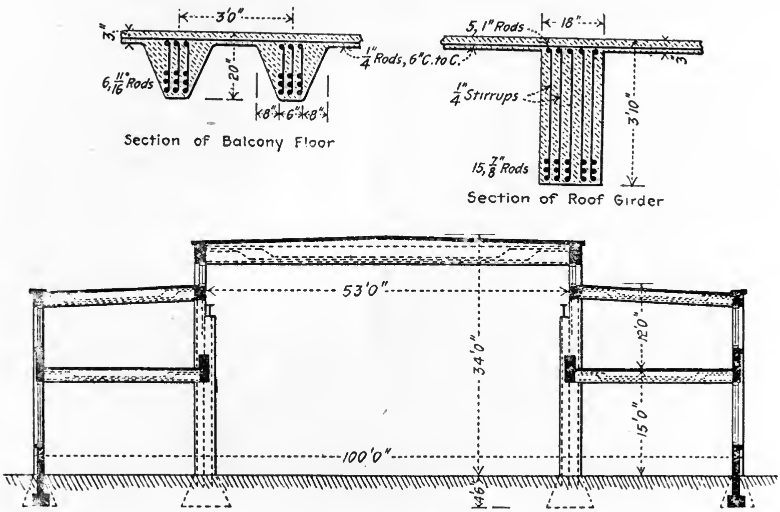


FIG. 86.—Machine shop of Fairbanks-Morse plant, Toronto, Canada.

6 in. at the bottom, and were placed 3 ft. apart on centers, each beam being reinforced with six rods, $\frac{11}{16}$ in. in diameter. A roof over the gallery was of the same general type with a 3-in. slab on beams of the same size placed 8 ft. apart. The tendency, however, in recent years is to use heavier slabs and fewer beams, and it is now common to find beams 16 to 20 ft. apart, at the columns only, without intermediate joists.

Slabs may be supported at all four sides or at two sides only,

the first being the strongest and most economical arrangement. With four side supports, the reinforcing steel will lie in two directions at right angles to each other, and for economy, the slabs should be continuous over their supports. Another economical plan is to use slabs 8 to 12 ft. long, supported on lines of beams resting directly on the columns without joists or cross girders. Roof framing is usually made of the same dimensions as the floors, for extra stories can then be added if desired without removing the roof or strengthening it. In some cases, however, as in the machine shop at Toronto, mentioned above, the roof framing is made lighter than the floor.

Wire mesh or expanded metal is more convenient for slab reinforcement than loose bars, for it is made at a factory and can be spread out in sheets. No. 10 gauge expanded metal with 4-in. mesh is often used and costs $3.50 per 100 sq. ft. Reinforcing metal in slabs generally costs 3½ to 4½ cents per square foot of floors when designed for a live load of 100 lb. per foot. Wire is economical because of its high tensile strength. Triangular mesh with strands of No. 4 wire 4¼ in. apart, united by a weave of lighter wire weighs 57 lb. per 100 sq. ft. and costs $2.30 at the mill. It is shipped in rolls up to 58 in. in width and 600 ft. in length.

Concrete slabs may have wearing surfaces of granolithic, boards or asphalt. A granolithic surface, as previously described under "Ground Floors," is by far the cheapest though uncomfortable to walk upon. When a wood floor is laid over a concrete

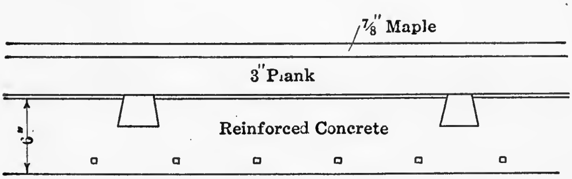


FIG. 87.

slab, the slab should first be covered with two layers of tar felt or heavy paper in pitch, or the lower course of plank may be bedded on tarred sand as was done in the Blake and Johnson factory at Waterbury, Conn. A shop at Woonsocket, designed by Mr. F. W. Dean, has nailing strips built into the 6-in. concrete slab, and to this is spiked a lower course of 3-in. plank which is covered with ⅞-in. maple (Fig. 87). The screeds

should be creosoted or coated with tar to prevent dry rot. An upper layer 1 in. thick of sawdust concrete into which nails can be driven, has sometimes been placed over the lower slab and beneath the floor boards. It should be made of equal parts by volume of cement and sawdust with two parts of sand.

Matched factory maple flooring $\frac{7}{8}$ in. thick over 2-in. spruce costs 13 cents per square foot, and $\frac{7}{8}$-in. yellow pine over 2-in. spruce costs 9 cents per square foot. Nailing strips or sleepers cost 4 cents per lineal foot in place, and 2- to 3-in. cinder fill between the strips costs 3 to 4 cents per square foot.

An asphalt wearing surface is both lighter and cheaper than wood. The concrete should first be washed with a mixture of melted tar and asphalt having just enough asphalt to make it hard when cold. The asphalt should be spread 1 in. thick and rubbed smooth with sand, as described under "Ground Floors." A car shed at Jersey City, designed by Mr. J. B. French, has a 4-in. roof slab of cinder concrete, reinforced with No. 23 triangular mesh.

Original and simple formulæ for proportioning concrete slabs are given herewith:

$$D = \sqrt{\frac{M}{1000}}$$

$$A = \frac{D}{12}$$

Where D is the depth of slab in inches from the upper surface to the center of the rods

M is the bending moment in inch pounds per foot width of slab

A, the area of steel in square inches per foot of width (Fig. 88).

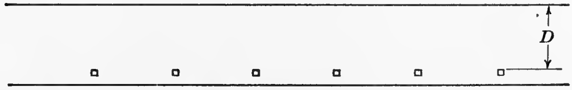


Fig. 88.

The weight of various concrete floor systems varies from 60 to 120 lb. per square foot, including the steel, which for the floor only, is from $2\frac{1}{2}$ to 6 lb. per square foot. Dry cinder concrete weighs from 50 to 75 lb. per cubic foot. The weight of floors depends, therefore, on the system used, the kind of material and their carrying capacity.

The cost of reinforced concrete floors and framing, under average conditions, is about as follows:

Floor slabs and beams without columns 35 to 45 cents per square foot of floor.
Complete reinforced concrete frames without walls 50 to 65 cents per square foot of floor.
Labor of mixing and placing concrete \$1.00 to \$1.50 per cubic yard.
Total cost of concrete in place \$6.00 per cubic yard.
Total cost of concrete in place including steel \$12.00 per cubic yard.
Forms and scaffolding \$5.00 per cubic yard.
Total cost of concrete, steel and forms, \$17.00 per cubic yard.
Cinder filling 3 in. thick over slabs, 4 cents per square foot.
Cinder filling 1½ to 2 in. thick, 3 cents per square foot.
Forms, 5 cents per square foot.
Or including beams, 10 to 12 cents per square foot.

Plain rods cost \$30 per ton while patent or deformed ones usually sell for \$40 to \$45 per ton.

The comparative cost of wood and reinforced concrete floors, with columns 16 to 18 ft. apart, as determined by the writer, showed that double wood floors on fireproofed steel beams, cost about 18 cents per square foot including the beams. Reinforced concrete beam and slab floors with granolithic finish cost from 25 to 30 cents per square foot, while concrete slabs with wood wearing surface will cost 12 to 15 cents per square foot additional. The concrete in the floors of a large building at Kansas City was, in 1908, laid at the rate of 50 cu. ft. per man per day. Under less efficient management, it had formerly been placed at only half that rate.

Flat Slab Floors.—Concrete floors with flat ceilings have some advantages over those which have exposed ribs or beams underneath them, because in case of fire, jets of water from fire hose or sprinkler systems are less obstructed on flat ceilings than when beams are used, and light is also better diffused. Shafting and sprinkler heads are more easily attached to flat surfaces than to those broken up with beams, the saving in these items amounting in some cases to 25 per cent. of the cost of installation. Forms or false work for flat ceilings cost 5 to 8 cents less per square foot when beams are omitted. A flat surface can, of course, be affected by suspending a ceiling of expanded metal and plaster below the floor beams, but this not only incurs extra expense for the ceiling itself, but it is no saving either in the height of the building or in the cost of forms. Another common method is that

in which hollow terra cotta tiles are placed between floor joists (Fig. 89) with comparatively close spacing. While this method reduces the cost of centering, it saves nothing in the floor thickness and includes the additional cost of tiles. Besides, the tiles are liable to crack and fall from the jars and vibration of machinery, exposing the building contents and the workmen to danger.

Floors with solid slabs without beams have a less total thickness than the combined depth of slab and beams, and the available head room in a story is correspondingly greater; or if a fixed clear-story height is needed, the total height of a building with flat slabs can be less than with slabs and beams. In a ten-story building with beams 16 in. deep, the total saving in the building height by using slab floors would be from 10 to 12 ft.

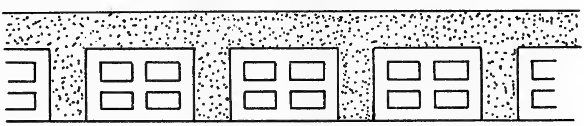


Fig. 89.

The chief objection to solid slabs supported directly on columns without beams is their uncertain stress conditions. For fifty years or more structural engineers have wrestled with the problems of uncertain stress. The merits of continuous girders, multiple truss systems and other uncertain types, have long been appreciated, and yet the uncertainty of their stresses has gradually but surely caused nearly all such systems to be discarded. One of these flat slab systems with the floor supported by bars radiating from the column tops at the four corners is suitable for column spacing not exceeding 20 ft. Floor panels 16 ft. square with a $7\frac{1}{2}$-in. rough slab not including the $1\frac{3}{4}$-in. strip filling will sustain a safe test of 800 lb. per square foot. Larger panels, 17 ft. square, with a rough slab thickness of $9\frac{1}{2}$ in. and a concrete unit stress of 800 lb. per square inch, is strong enough for a live load of 250 lb. per square foot, with $1\frac{1}{2}$ per cent. of steel reinforcement at the top and bottom of the slab. If $1\frac{1}{2}$ per cent. of steel is used at the top only, the required thickness of rough slab would then be 12 in. This type requires about 40 per cent. more steel than floors with beams and thinner slabs, but the difference is partly offset by the lower cost of centering.

TABLE XVII.—THICKNESS OF FLAT REINFORCED CONCRETE FLOOR SLABS SUPPORTED AT THE FOUR CORNERS ONLY

Span, feet	Total load per square foot, pounds	Slab thickness, inches
12	100	4
	300	6
	500	7½
14	100	4½
	300	6½
	500	7½
16	100	5
	300	7
	500	8
18	100	5½
	300	7½
	500	9
20	100	6
	300	8
	500	10
25	100	7
	300	10
	500	11

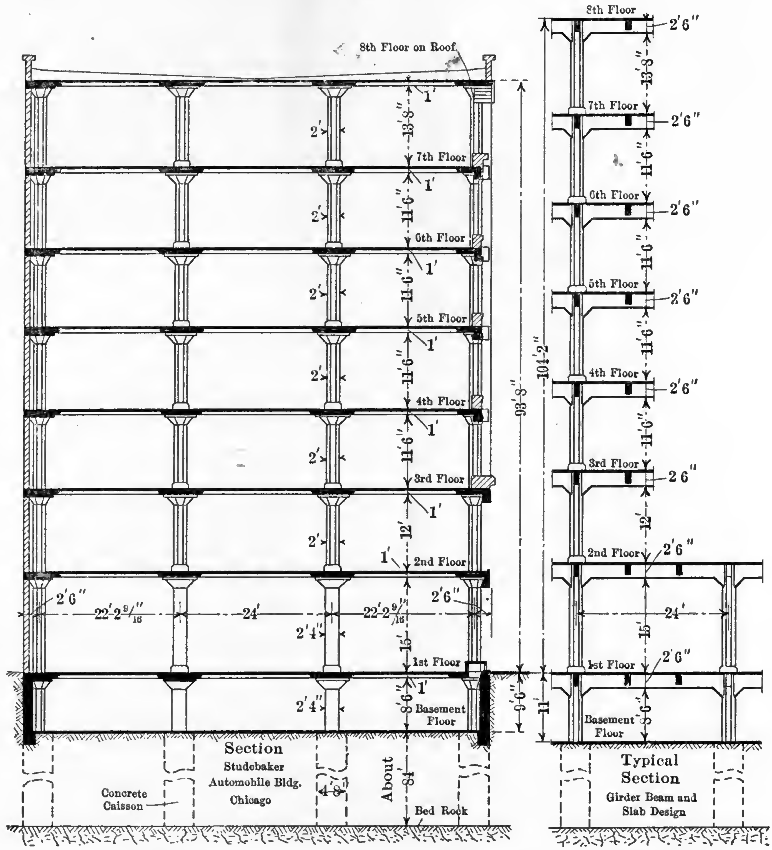
In order to determine the comparative cost of reinforced concrete buildings with flat slab floors, and with floors of combined beams and slabs, estimates were made on a ten-story building 109 ft. wide and 580 ft. long, which showed that the design with flat floor slabs, including a patent royalty of 1½ per cent., had a cost only 2 per cent. less than the design with slabs and beams.

The itemized cost of concrete per cubic yard, of 1–2–4 mixture, was as follows:

Concrete, 1⅔ barrels at $1.10	$1.80
Sand, ½ yard	.40
Stone, 1 yard	1.00
Labor	1.00
Sundries	.10
Total	$4.30

Concrete in columns had an additional cost for labor of 70 cents per cubic yard.

It is well known that flat slabs supported only by columns at the four corners are not subject to exact analysis and are pro-



Paneled-Floor Construction

Typical Section; Girder, Beam and Slab Design

FIG. 90.—Paneled ceiling, compared with beam and slab design for Studebaker Co. building, Chicago.

portioned chiefly from experiments, though the slabs are sometimes assumed to act as cantilevers from the flaring column heads. This condition in itself should give the preference to other and better forms which can be proportioned with certainty. Fortunately such forms are available, for slabs with reinforcement in two directions may be supported on other wide and

shallow slabs or beams continuous over the columns, forming large panels in the ceiling, corresponding with the position of the columns. The esthetic effect of these panels is much superior to a wholly flat surface, and the type is by far the best yet available (Fig. 90). In the Sharpless Building in Chicago designed by Mr. T. L. Condron, with columns about 18 ft. apart, the main beams are 6 ft. wide and only 1 ft. deep, with an 8-in. intermediate slab, the weight of steel in the floor being 5½ lb. per square foot. Columns have a uniform diameter of 2 ft. from the basement to the tenth floor, the column caps under each floor having a diameter of 4 ft. A similar arrangement is used in the Studebaker Building in Chicago in which the columns are 24 ft. apart.

CHAPTER XVI

WALLS, PARTITIONS AND OPENINGS

Brick Walls.—Brick continues to be a favorite type for the outside walls of shops and factory buildings, because of its neat appearance. It may be used for the whole exterior wall, or as a veneer over the concrete structural parts. Solid brick walls are laid with English or Flemish bond, and the bricks should be wet before laying to prevent the extraction of water from the

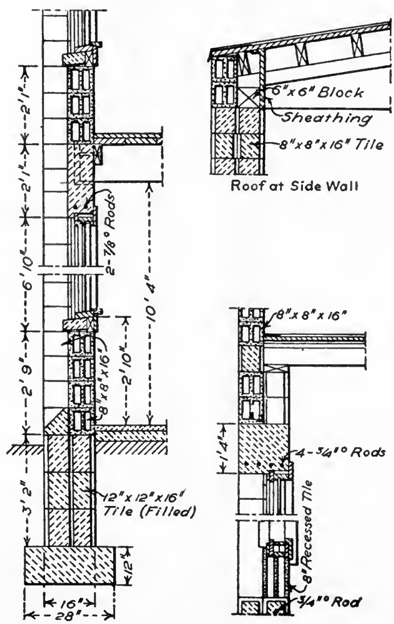


FIG. 91.—Hollow concrete tile walls. Hunter Illuminated Car Sign Co., Flushing, Long Island.

mortar. About one-fifth of brick walls is composed of mortar, which should be made by mixing one barrel of lime, four of sand, and one-half barrel of cement, with one and a half barrels of water. When laid up in courses, brickwork will settle about 1 in. for every 50 ft. in height. One man can lay 1000 to 1200

bricks per day in plain walls, and 4000 to 5000 per day in massive blocks such as engine beds or foundations. Doors and window frames should be made of the proper size to suit the brick courses without cutting. Brick walls, either 8 or 12 in. thick, cost about the same—45 cents per superficial foot—for the material saved in the 8-in. wall is offset by the greater labor cost of laying it.

Vitrified Tile Walls.—Walls of vitrified tile are light and do not absorb water. Blocks are usually 8 by 12 by 18 in., and when laid in the wall cost 25 cents per superficial foot, or 38 cents when plastered on both sides (Fig. 91).

Concrete Block Walls.—Concrete blocks have a light weight and low cost, but have the objection of being rather porous. When the regulations of labor unions are such as to require the

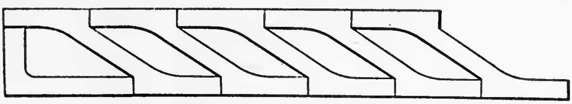


FIG. 92.—Hollow concrete block wall.

employment of union masons or bricklayers for placing them, the cost of this kind of wall will be increased. A recent type is shown in Fig. 92.

Walls may also be made of 8-in. hollow concrete tile blocks 8 by 8 by 16 in., with cement and aggregate mixed in the proportion of 1 to 3. Stones in aggregate should not exceed 5/8-in. diameter. The cost of laying these tiles with common labor is only about one-third that of laying brick and the final cost of

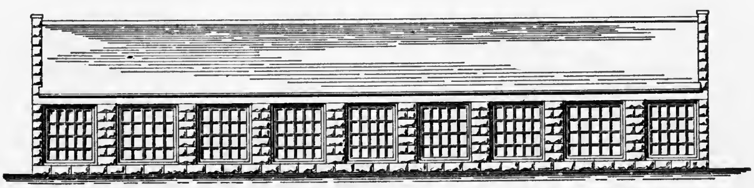


FIG. 93.—Building with concrete block walls.

the finished walls has been found to be only 40 to 75 per cent. as much as ordinary brick and 25 to 50 per cent. as much as cut stone or face brick (Fig. 93).

Cement Brick Walls.—Cement brick was successfully used by the Plymouth Cordage Company in a two-story shop, 114 ft. wide and 430 ft. long. It contains 2,400,000 bricks made with

hand machines, the proportion of cement and sand being 1 to 3. Six kinds of bricks were made, and the rate at which they were produced is as follows:

Common cement bricks	14,000 per day
Face bricks	9,000 per day
Radius bricks	8,000 per day
Corner bricks	8,000 per day
Headers	9,000 per day
White bricks	9,000 per day

Mortar for laying cement bricks contains cement and sand in the proportion of 1 to 3, with a half sack of lime added for each barrel of cement. The waste was only one-half of 1 per cent. and the finished cost was found to be 12 per cent. less than clay bricks.

Concrete Walls.—Concrete walls may be either self supporting and solid to directly sustain imposed loads, or they may be used as curtains between the structural members of steel or concrete. The latter method is now generally used and is the cheaper and more convenient, as the structure can be erected first and the walls filled in afterward. Exterior concrete curtain walls should never be thinner than 4 in., and they may be veneered with brick, as on the Bullock Electric Company's shops at Cincinnati. For the purpose of anchoring the brick, strips of metal should be tacked lightly to the inside of the wood forms and built 4 in. into the concrete. When the forms are removed, these anchors can be straightened out and built into the brick joints, thus firmly uniting the two materials. When the walls are not veneered, the concrete surface may be treated by any of the methods given in the chapter on "Concrete Surface Finish." The original building for the United Shoe Machinery shop at Beverly, Mass. (Fig. 94) was made with solid walls, but when making additions in 1907, the walls were cored. Concrete curtain walls 8 in. thick, when cast in place with double wooden forms after the skeleton is finished, cost about 40 cents per square foot, but when poured at the same time as the columns, the cost is increased to about 48 cents per square foot. Curtain walls or filling slabs 4 in. thick, when poured as described above, cost 35 cents per square foot. It appears, therefore, that walls of 8-in. concrete and 12-in. brick cost about the same (Fig. 95).

Monolithic concrete walls have, however, been recently made

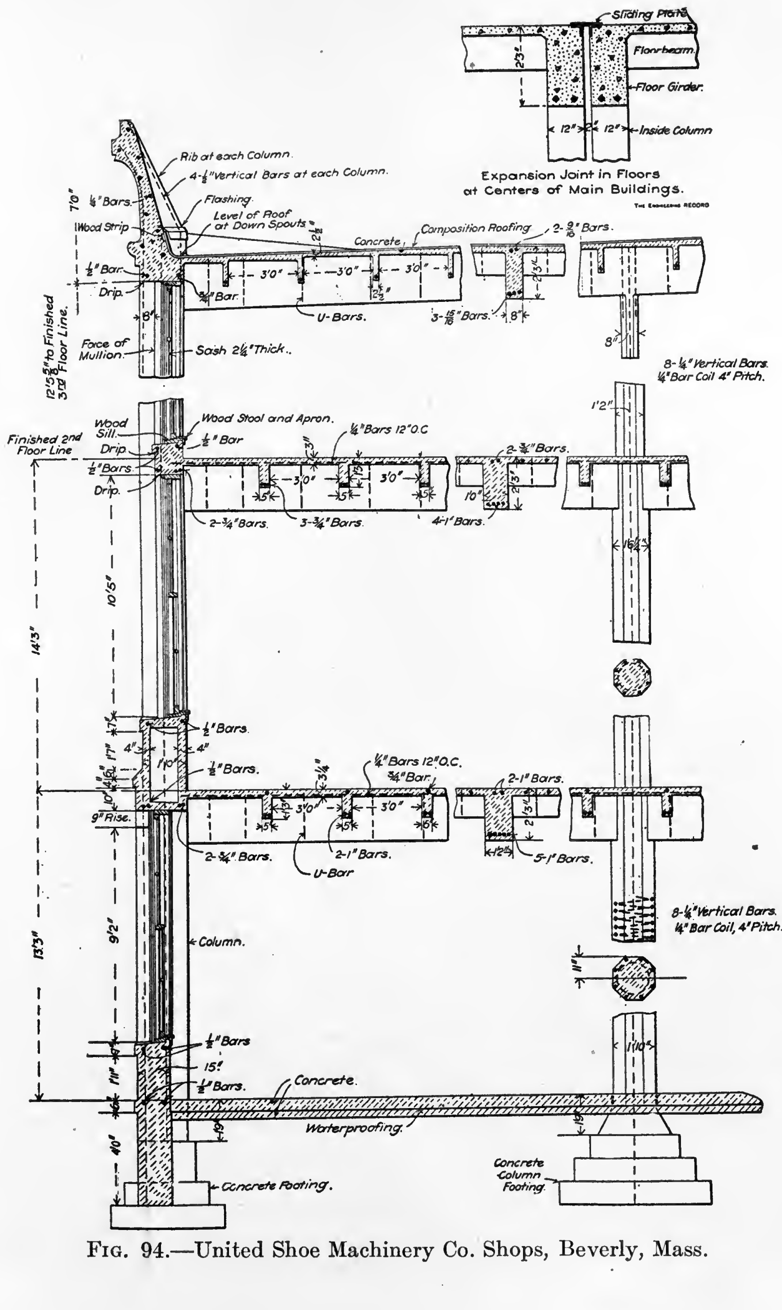


FIG. 94.—United Shoe Machinery Co. Shops, Beverly, Mass.

with removable metal forms at a great saving in expense, the actual cost with unskilled labor being as follows:

Twelve-inch monolithic concrete walls,[1] made as above, cost

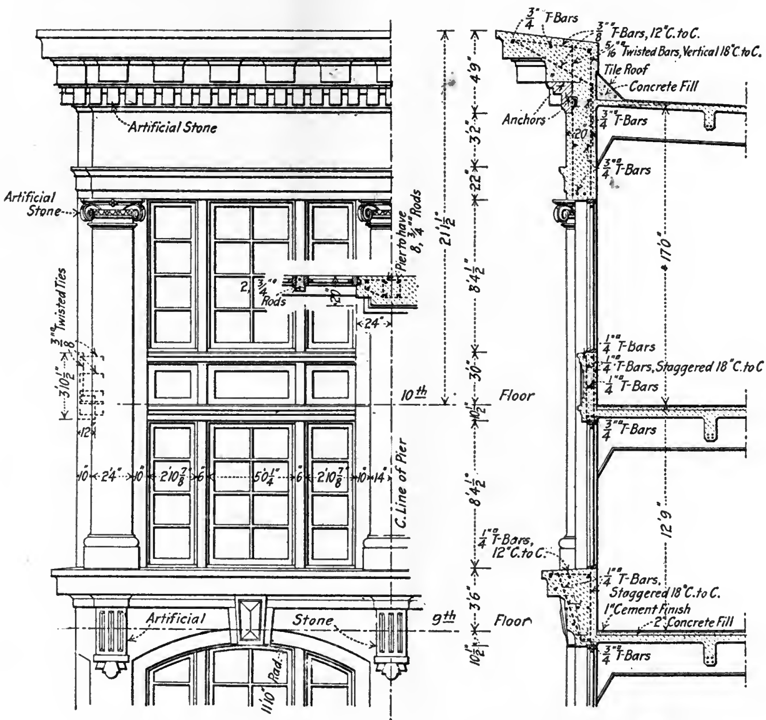


FIG. 95.—Details for concrete building.

Material........................	11.5 cents per square foot
Mixing and placing.............	3.0 cents per square foot
Movable metal forms............	1.5 cents per square foot
Total......................	16.0 cents per square foot

Six-inch monolithic concrete walls cost

Material........................	5.75 cents per square foot
Mixing and placing.............	1.5 cents per square foot
Movable metal forms............	1.5 cents per square foot
Total....................	8.75 cents per square foot

If a surface coat is desired it can be added at an additiona lcost of 2½ cents per square foot. The concrete itself in the 6-in.

[1] *Cement Age*, February, 1912.

walls cost $5.40 per cubic yard or 20 cents per cubic foot. The cost of the removable steel forms has been found to be about one-half cent per square foot for each face, while wood forms would cost at least 5 cents for each face. Unskilled labor can be used on monolithic work, whereas block walls must usually be laid by masons at a higher rate of wages. These costs are remarkably low for a wall that is substantial and that can be made attractive at an aditional expense of 2 or 3 cents per square foot, as elsewhere described. Walls 3 to 4 in. thick, of previously moulded concrete slabs, can be made and erected at a cost of 8 to 10 cents per square foot, but they lack the rigidity of monolithic work. (See "Separately Moulded Members".)

Wooden Walls.—These are but little used in modern shops and should be covered with slate, shingle, or metal siding either stamped or rolled. Plank with splines or tongue and groove may stand vertically and be fastened to horizontal girths, and square edged plank may have the vertical joints covered with ½-in. battens. If the planks are laid diagonally, they form substantial bracing for the building, though the diagonal cutting causes some waste. Planks should be horizontal when the walls are covered with slate or metal. A weather boarded wall over plank not including the framing, will cost 10 to 12 cents per square foot.

The comparative cost of frame, veneer and solid brick walls is as given in the following table:

TABLE XVIII

FRAME

Plastering	$0.24 per square yard
Lumber, 18 ft. at 2 1/2 cents	.45 per square yard
Siding, 12 ft. at 3 1/2 cents	.42 per square yard
Painting per yard, two coats	.17 per square yard
Paper per yard put on	.03 per yard square
Back plaster	.20 per square yard
Total	$1.51 per square yard

BRICK VENEER

Plastering	$0.24 per square yard
Lumber, 18 ft. at 2½ cents	.45 per square yard
Paper	.03 per square yard
Face brick, 63 at 3 cents	1.89 per square yard
Total	$2.61 per square yard

Solid Brick

Face brick, 63 at 3 cents	$1.89 per square yard
Common brick, 126 at 1 cent	1.26 per square yard
Furring	.06 per square yard
Plastering	.24 per square yard
Total	$3.45 per square yard.

Brick veneer will therefore cost for the whole building 25 per cent. more than frame, and solid brick about 40 per cent. more than the frame building.

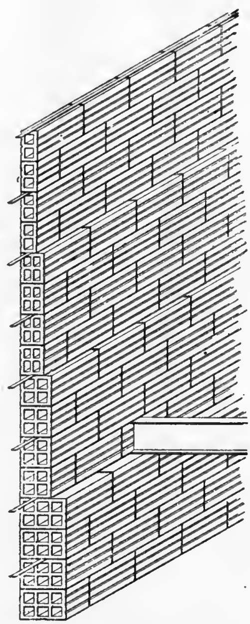
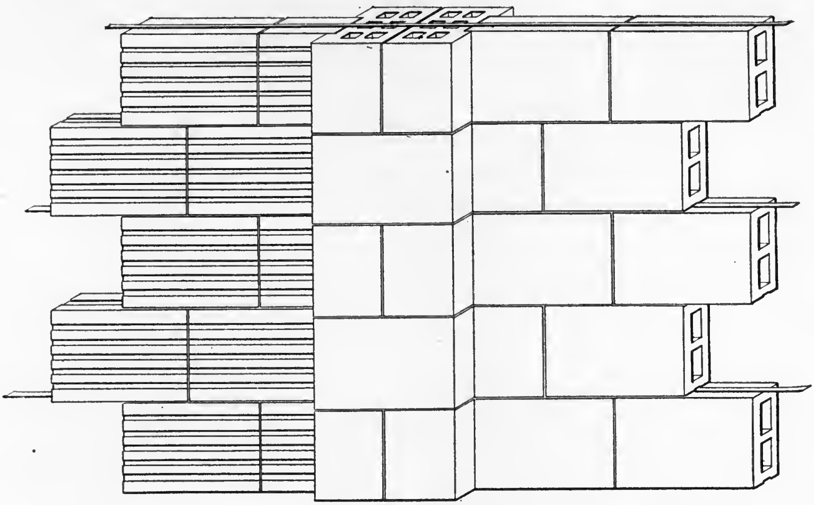


Fig. 96.—Tile wall for four-story building. Thickness 4 to 12 in.

Partitions.—Departments which generate noise, gas, smoke, fumes, or dust must be partitioned off from other parts of the shop, and these departments will include rooms for polishing, grinding, rattling, Japanning and painting. These partitions are cheapest and most conveniently made of thin terra cotta blocks or hollow tile 2 to 4 in. thick (Figs. 96–97) for they can easily be removed when other arrangement is needed. When removal and rearrangement is improbable, partitions may be



"Phoenix" Wall, with piers, smooth or ribbed for plastering

Fig. 97.—Tile wall with pier. Blocks either smooth or ribbed for plastering.

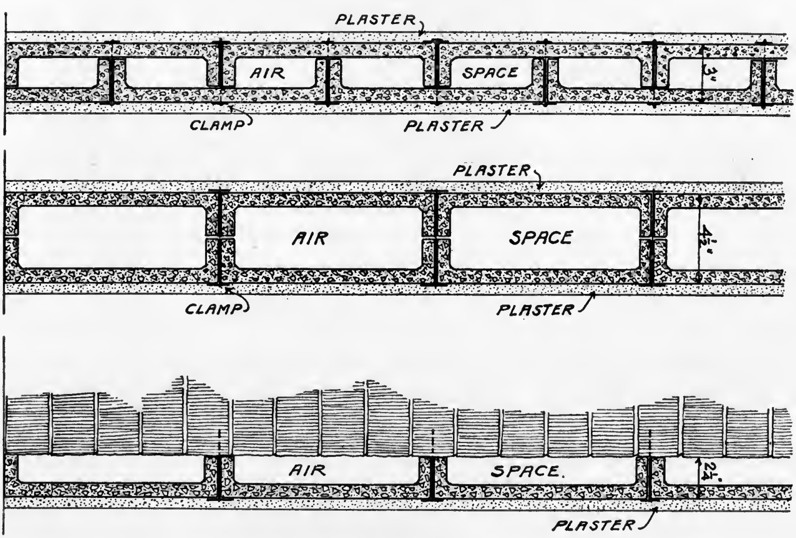


Fig. 98.—Concrete channel block partitions and wall furring.

of reinforced concrete (Fig. 98) or expanded metal on light framing. Mackite blocks 2 in. thick have frequently been used and are easily erected, as they are 12 in. wide and 4 feet long. As the blocks are soft, they should be coated with adamant plaster. Some makers of expanded metal also manufacture metal studs with outstanding prongs ready for clinching when the expanded metal is in position. These studs greatly simplify the work of partition building. Concrete and expanded metal walls 2 in. thick cost 20 cents per square foot.

Windows.—One of the chief differences between old manufacturing buildings and new ones is in the amount of light admitted, modern ones frequently having three to four times as

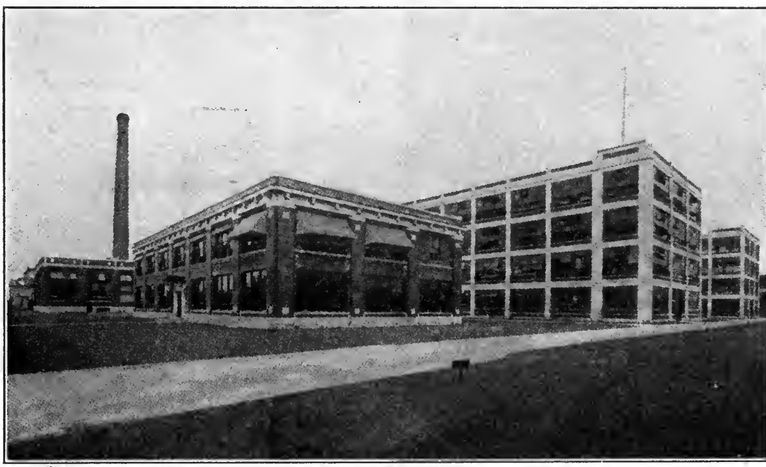


Fig. 99.—A modern plant for Dodge Brothers Co., Detroit.

much as their predecessors. In fact, the exterior walls are now composed chiefly of glass, many having window areas of 70 to 80 per cent. of their exterior surface (Fig. 99).

When walls have brick on the outside, the size of window frames should be made to suit an even number of brick courses to avoid cutting the brick. Cypress was formerly used for large sash and frames, but it has been found to warp easily, and pine is, therefore, preferred. Nearly all of the latest shops, however, have steel frames and sash, provided with opening mechanism, to operate a number of sash at once (Fig. 100). Trunnions should turn in brass sockets to avoid any possibility of binding from rust.

A good arrangement for side wall windows is to have three tiers of sash, the upper one being pivoted for ventilation and the two lower ones hung. In cold climates windows should be double glazed to save expense in heating.

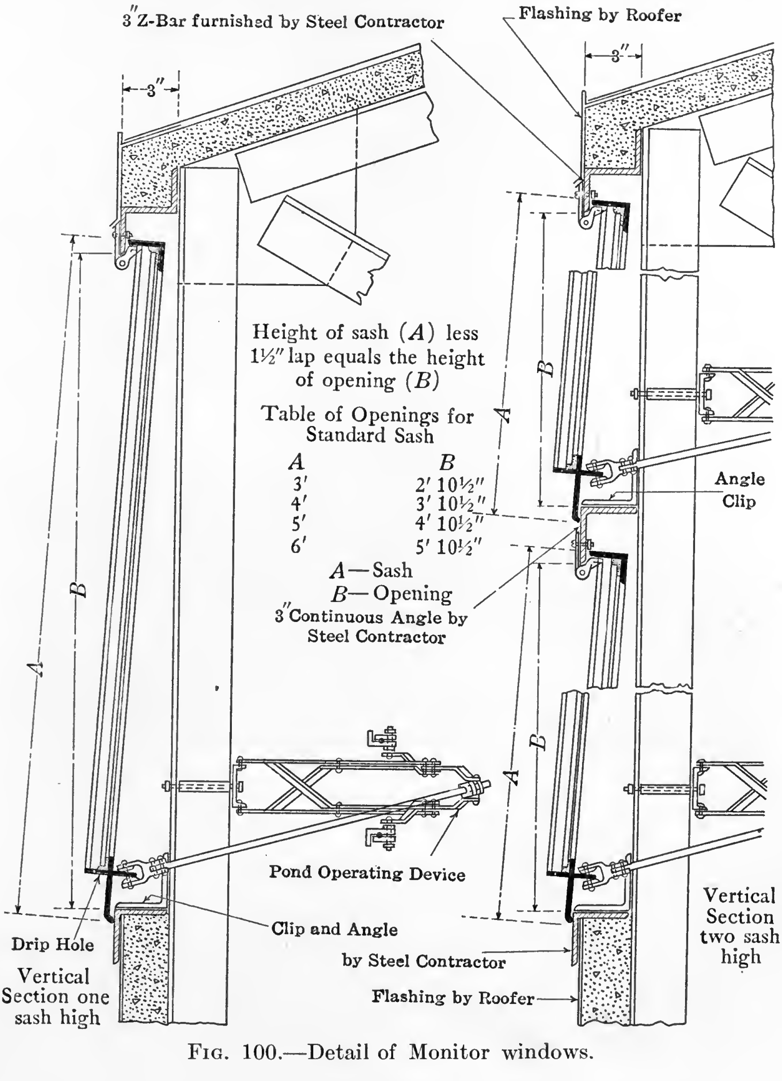


FIG. 100.—Detail of Monitor windows.

Doors.—All doors in multi-story buildings should be fireproof, and at the stairs they should have fusible link attachments, tin-clad doors being preferable to sheet metal ones.

Storage buildings are often provided with double sets of doors, solid ones to close at night, and inner ones for use during the day with open slats which will allow air to circulate.

Car shed doors 10 ft. by 16 ft. are economical and convenient when made of wood and hung on cast-iron eyelets built into the wall. They may have glass in the upper panels, and the cost should not exceed about $100. Rolling steel shutters for the same place would probably cost $160 to $170.

In special places where loading cranes must extend out through the side walls of a building to cover an adjoining line of railway, a rolling steel shutter may be mounted on wheels to move out from the building in advance to the crane and return again to its original position on the side of the building, when the crane is indoors. For more complete details of windows and doors for shops, see Tyrrell's "Mill Buildings" pages 331-373.

CHAPTER XVII

ROOFS AND ROOFING

The weight and permissible roof inclination for different kinds of roofing are given in the following table. From this it appears that either the inclination or its covering can be selected arbitrarily, but when a choice of one of these has been made, the other must conform to it. The slope must be great enough to shed water over the joints or seams of the diffierent coverings, and flat enough in some cases to permit the covering to be placed.

TABLE XIX.—ROOF COVERING—WEIGHT AND LIMITS OF SLOPE

Material	Slope (in degrees) from the horizontal		Weight in pounds per square foot
	From	To	
Corrugated iron on purlins	5	30	5
Zinc on boards	0	30	5
Zinc on purlins	0	30	7½
Lead on boarding	Flats and	gutter only	10
Lead and purlins	Flats and	gutter only	12½
Slates on boarding	20	45	12½
Slates and purlins	20	45	15
Tiles on battens and rafters	30	70	17½
Tiles and purlins	30	70	20

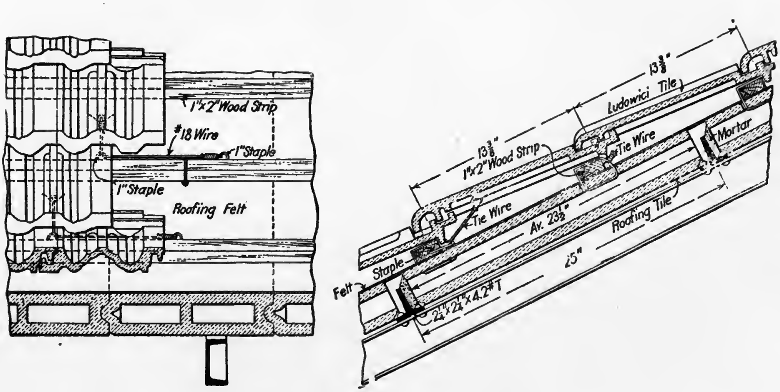


Fig. 101.—Tile roof details.

Roofing is made in great variety, including tile, slate, composition, sheet metal, and wood shingles, and these are supported directly on purlins or on plank or a filling of concrete between them, such filling making excellent roof bracing. Boards should be strong enough to support a man's weight, and the maximum span lengths for different thicknesses are as given in the following table:

TABLE XX.—ROOF BOARDING—THICKNESS AND SPAN

Thickness in inches	Maximum span
$\frac{5}{8}$	2 ft. 8 in.
$\frac{3}{4}$	3 ft. 6 in.
$\frac{7}{8}$	4 ft. 1 in.
1	4 ft. 8 in.
$1\frac{1}{8}$	5 ft. 3 in.
$1\frac{1}{4}$	5 ft. 10 in.
$1\frac{3}{8}$	6 ft. 5 in.
$1\frac{1}{2}$	7 ft. 0 in.

Buildings in which acid fumes are generated, as in brass foundries, must be covered with an indestructible material such as slate. Uralite has been used in England, its cost being about the same as No. 20 corrugated iron.

Flat roofs should be framed like floors, excepting that they should have a slope of at least 1/2 in. per foot, and they are most conveniently covered with tin, tar and gravel, or some kind of composition.

Tin roofing (M. F. Brand) is sold in boxes containing 110 sheets and costs about $7.25 per box. The actual cost of laying it will be about 6 cents per square foot additional. Previous to laying the metal, the roofing boards should be overlaid with three layers of tar paper fastened down with nails and tin washers.

The quantities of material required to lay one square of tar and gravel roofing, are:

Sheathing paper	100 sq. ft.
Tarred felt	80 to 90 lb.
Coal tar pitch	120 to 160 lb.
Gravel	400 lb., or slag 300 lb.

Felt weighs 15 lb. per 100 sq. ft. with an addition of 10 per cent. for laps. When burlap and felt are used the cost will be about \$4.50 per square (100 sq. ft.), or slabs can be covered with felt and asphalt.

Concrete Roofs.—Concrete, while somewhat heavier than wood, is often favored because it is fireproof, and when covered with roofing material to shed water, cinder concrete can be used, as on the buildings at the Brooklyn Navy Yard, where the 3½-in. slabs of concrete and expanded metal are covered with slate. If a concrete roof with a considerable pitch or slope is to be covered with tile, wood nailing strips parallel with the eave should be cast into the slabs.

Concrete Shingles.—Shingle machines are sold for \$100 to \$200, that are quite similar to those for making concrete blocks. One make of machine produces a cement shingle 8 in. wide, 16 in. long, and ½ in. thick at the butt, each shingle being reinforced

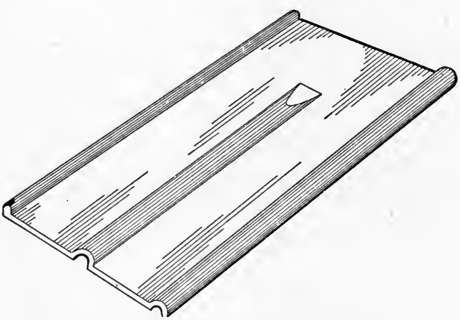


Fig. 102.—Water proof concrete tile.

with metal which projects in loops at each side for nailing. They are composed of cement and sand in the proportion of 1 to 1½ mixed dry, with water added afterward. At the end of twenty-four hours they are removed from the moulds and stacked in the yard for thirty days, being sprinkled occasionally for a few days after making them. The cost of labor and materials will vary in different sections, and hand machines will make from 300 to 400 shingles per day.

Concrete Tile.—Waterproof concrete tiles (Fig. 102) supported directly on purlins, have come rapidly into use and have many advantages. They were first made in the United States in 1902. Their extreme size is 26 by 52 in. and ⅞ in. thick, and they lay

24 by 48 in. to the weather, weighing in position, about 13 lb. per square foot. Purlins must be 4 ft. apart on centers. Tiles are reinforced with number 18 expanded metal. With this roofing glass skylights are unnecessary, as any desired proportion of glass tiles can be substituted for the regular ones, and they can be arranged as desired, either in clusters or in small scattered areas.

CHAPTER XVIII

NOTES ON SPECIAL BUILDINGS

The Drafting Office.—The importance of the drafting office can better be comprehended when it is considered that not less than $50,000,000 in wages is paid annually to draftsmen in the United States, and other countries can doubtless show similar proportions. As the drafting room is the place where inventions are made and developed, and details of construction determined, every facility should be provided that will assist in these directions. Engineers and designers should not be tied down to routine work or to exact hours, for such restrictions are a hindrance to thought and study. An hour or two over a drawing board at one time without interruption is enough, and the day's work generally should not exceed eight hours. It should be remembered that in this office, wealth can either be made or lost for the factory owners, and the greatest latitude should be given to men who are capable of creating profits and saving in expense. Those who have the faculty for design should not be hampered, for the day is short enough, and when fatigued with trivial duties even an inventive mind must take time to rest.

The drafting office (Fig. 103) in all its particulars should, therefore, be made to assist its occupants in doing their best. Good light, air, and a comfortable degree of warmth are essentials, but nothing is more important than order. Attention cannot be concentrated on a subject to the best advantage in a room where papers and litter of every kind are piled about, and since papers must accumulate rapidly in a drafting office, there should be facility for filing them where they can be easily reached. Room interiors and furniture should preferably be finished in light tones, for dark colors absorb light. Upper sash may have ribbed glass which diffuses daylight better than plain, but the lower glass should be clear, that men may rest their eyes by occasional distant views. Each window should have two shades, one for each sash. The office must also be well ventilated, for clear thought is impossible in a foul atmosphere, and rooms

should, therefore, be high and in warm weather should have fans. They should be large enough that each man will have not less than 100 sq. ft. of floor space, and there should be enough toilets and wash bowls to provide one for every twelve to fifteen occupants.

Office equipment should be selected with a view to promoting order and convenience both as to quantity and kind of furnishing. Inclined or horizontal drawing boards are better than vertical ones, because standing all day with extended arms before a vertical board is too fatiguing. One or more illuminated drawing

Fig. 103.—A drafting office.

boards are convenient for tracing blueprints. The board is, in fact, a piece of plate glass in a wooden frame with facility at the edges for clamping the drawing down. It has electric lights beneath the glass to illuminate the blueprint from below. A small printing press is a saving of time in putting on titles or other wording that is repeated on several sheets. It can also be used for printing time cards, office forms, blanks and similar papers. Printers' ink which dries slowly and is likely to smear should be

sprinkled over with powdered chalk or soapstone. Draftsmen should also have the use of a writing machine for tabulating or copying, and carbon negatives may be made on thin paper that can easily be blueprinted.

A hektograph capable of making from sixty to eighty duplicates is useful for copying simple sketches. The block is composed of white lead and glue poured into a shallow pan and allowed to harden. Drawings for use on the hektograph should be made on cloth with special ink, and as the ink does not dry, the ruler should be raised slightly above the cloth on border strips to avoid smearing it. These inks can be bought in several colors. This method of copying is very useful for small drawings, and especially for blank forms such as bolt and rivet lists, for when blanks are made, three or four copies can be filled out at one time with the use of carbon paper in a typewriter.

Other simple sketches may be drawn directly on paper and several carbon copies made by ruling over a hard surface, such as polished wood or a sheet of metal.

A large camera is extremely useful in connection with the drafting room. Photographic views of buildings or machinery can be reproduced in pen and ink sketches by tracing over the photograph, and from these sketches, zinc etchings can be made at a cost of 5 cents per square inch. The camera is also useful for reproducing drawings and reducing them to a small size which can be conveniently handled, especially for outdoor use or erection purposes. When reducing large drawings by photography, it is only necessary to use solid lines, and large open printing which can be read easily on the reduction. Photographs and blue-prints can be mounted on cards or pasteboard for the shop, and shellaced, and then if they become soiled they can easily be cleaned.

The cylindrical arc light blueprinting machine is the best and most reliable for all kinds of weather, but the office should also have one or more sunlight frames. Whenever alterations are made on blueprints that have already gone to the shop, the date of such alterations should be noted thereon. Blueprints may be photographed by changing them to brown in the following way. The prints should first be immersed in a dilute solution of ammonia until the blue disappears. They are then washed in water and placed in a weak solution of tannic acid until they turn brown. The prints should again be washed with water and dried, when they can easily be photographed.

Machines are now available which will transform drawing paper into a translucent sheet like tracing paper that can be blueprinted, and this method may sometimes be used to advantage when drawings have been made on paper instead of cloth.

A record book of contracts should be kept by the chief draftsman or office manager, and this should consist of duplicate pages alternately white and yellow, the yellow being used for a carbon copy. Then, when work in the drafting office is assigned, the duplicate copy can be torn out and handed to the draftsman.

Machine Shops.—These buildings must have space for planers, lathes, and other tools, as well as storage room for completed

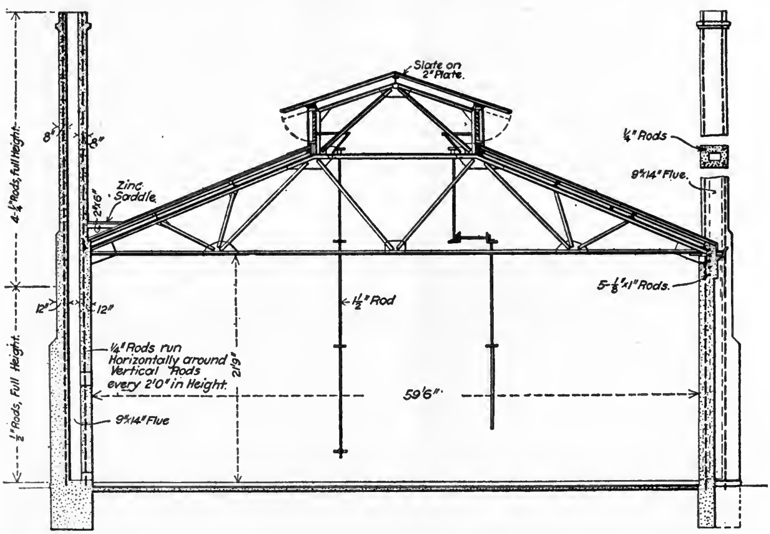


Fig. 104.—Forge shop. United Shoe Machinery Co., Beverly, Mass.

and partially completed work, and space for assembling machinery and for toilets, lavatory and shop office. Some form of wooden floor as described in Chapter XIII, is the best, as these are comfortable to stand on, can be kept clean, and when sharp-edged tools drop, they are not injured. The absence of dust in machine shops is important, and especially the kind that frequently rises from a concrete floor, for it settles in the machinery bearings and is likely to injure them. Other requisites common to all modern shops, such as light and ventilation, are likewise appropriate here.

Forge Shops.—Blacksmith shops will contain steam-hammers,

bulldozers, forges and anvils, furnaces, iron and fuel, and space for a wash room and for an office. They should have provision for heating in cold weather without depending on the forge fires. One chimney (Fig. 104) is generally enough for six ordinary forges, but for down draft only one chimney is needed for the whole building. Material should be stored in a separate warehouse and brought into the shop only as required. The clear height underneath the trusses should not be less than about 14 ft., and side walls should have at least 6 ft. of continuous sash. Artificial light will be bright enough with 6-ampere arc lamps hung 40 ft. apart. The best floor for a forge shop is a 5-in. layer of cinders over a base of sand and gravel. The cinders should contain just enough clay to cement them well together, and the floor should be rolled and sprinkled every day for a month. To prevent mud forming from the cementing clay, the surface should be covered with a layer of sand.

Foundries.—The foundry must have space for machine moulding, bench moulding and core making, as well as for sand

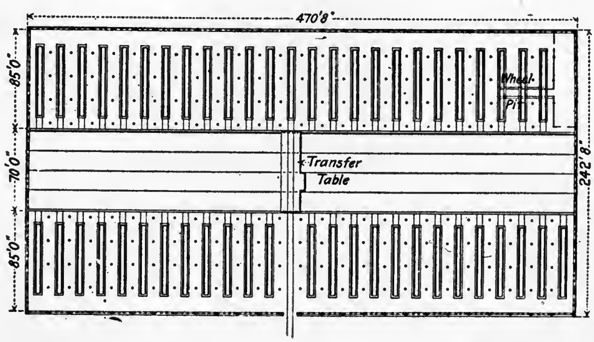


FIG. 105.—Rectangular engine house.

mixing and storage, coke storage, sand blast and cleaning, charging and cupola floors, supply room, lavatories and office. There is a decided tendency in foundries toward the use of square buildings. Cupola rooms are set in the side bays away from the main shop. Transportation on the ground only is not always economical, and there should generally be overhead appliances as well. Cranes and trolleys should hang from a heavy system of trusses, leaving the floor free from obstruction of columns.

Round Houses.—In choosing between rectangular (Fig. 105) and circular engine houses, the first form requires about 50 per

cent. less floor area than the second, and has straight walls and less doors, making a rectangular building altogether cheaper than a round one. But the latter type has other advantages and continues in favor.

The dimensions of a round house will depend on the length of engines (Fig. 106). Turntables moved by an electric tractor or compressed air must be a few feet longer than the engine, and enough space must be left for doors to open between the table and the inner engine house wall. Doors should be 10 ft. wide,

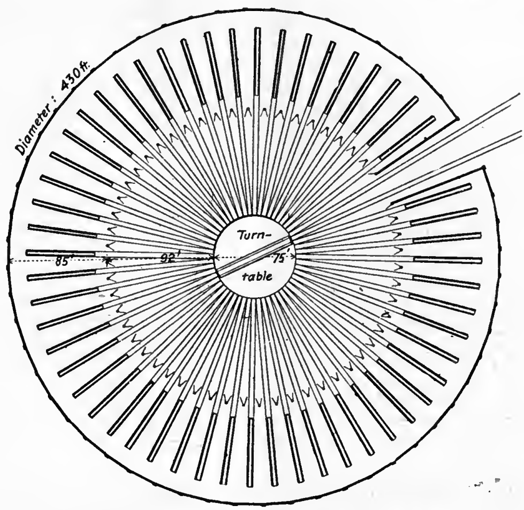


FIG. 106.—Circular engine house.

thus leaving some clearance at each side of the engine (Fig. 107). By fixing on a minimum width of pilaster between the doors, the panel length at the inner wall will be determined. Sliding, swing and rolling doors have all been used, but as those which swing on hinges at the side are in danger of being clogged with snow and ice, a balanced door is sometimes preferred. Steel rolling doors cost more than either of the others. The width of the building should be 10 to 15 ft. greater than the length of the engine, allowing space for workmen to pass when the doors are closed. A width of 92 ft. is generally enough for ordinary large locomotives, but Mallet engines, some of which have a length of 120 ft., will require special housing. Figure 108 shows a turntable in use on the A. T. & S. F. Ry. for turning Mallet engines.

Walls should be of brick or concrete blocks, because monolithic concrete is too inconvenient to repair when damaged, though it is suitable for the foundations. As runaway engines occasionally go through the outer wall, it is better to place an arch or lintel at the end of each track, which would prevent the roof from falling if the walls should be broken down. The building should be divided by occasional fire walls, six to eight stalls apart, and these should extend above the roof.

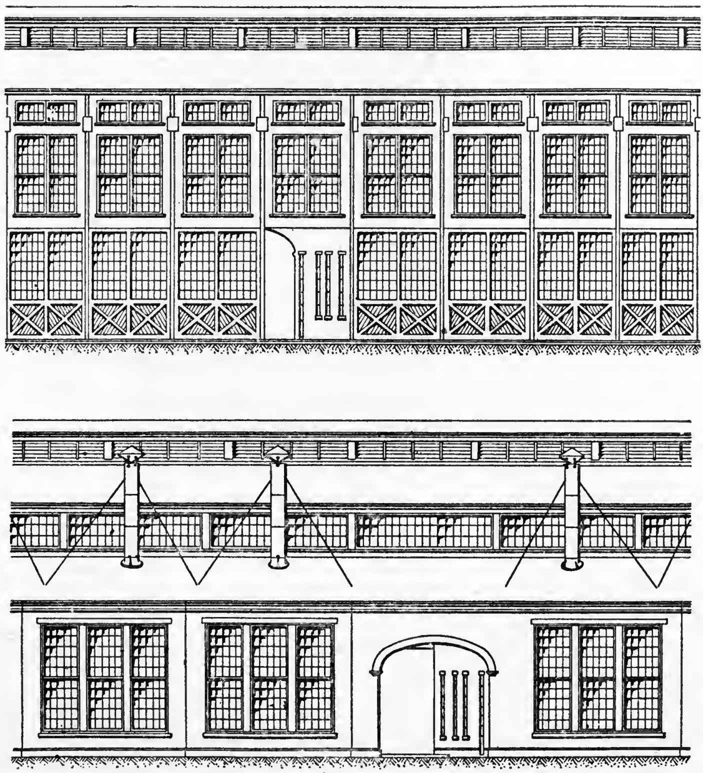


FIG. 107.—Inside and outside elevations of roundhouse.

Vitrified brick grouted in tar or pitch makes the best floor. Wood wears out too quickly, and concrete with granolithic top is easily cracked or broken under the weight of trucks and wheels. Pits under the tracks should be 50 to 60 ft. long, $4\frac{1}{2}$ ft. wide and 2 to $3\frac{1}{2}$ ft. deep, and they should be convex at the bottom allowing water to drain to either side (Fig. 109).

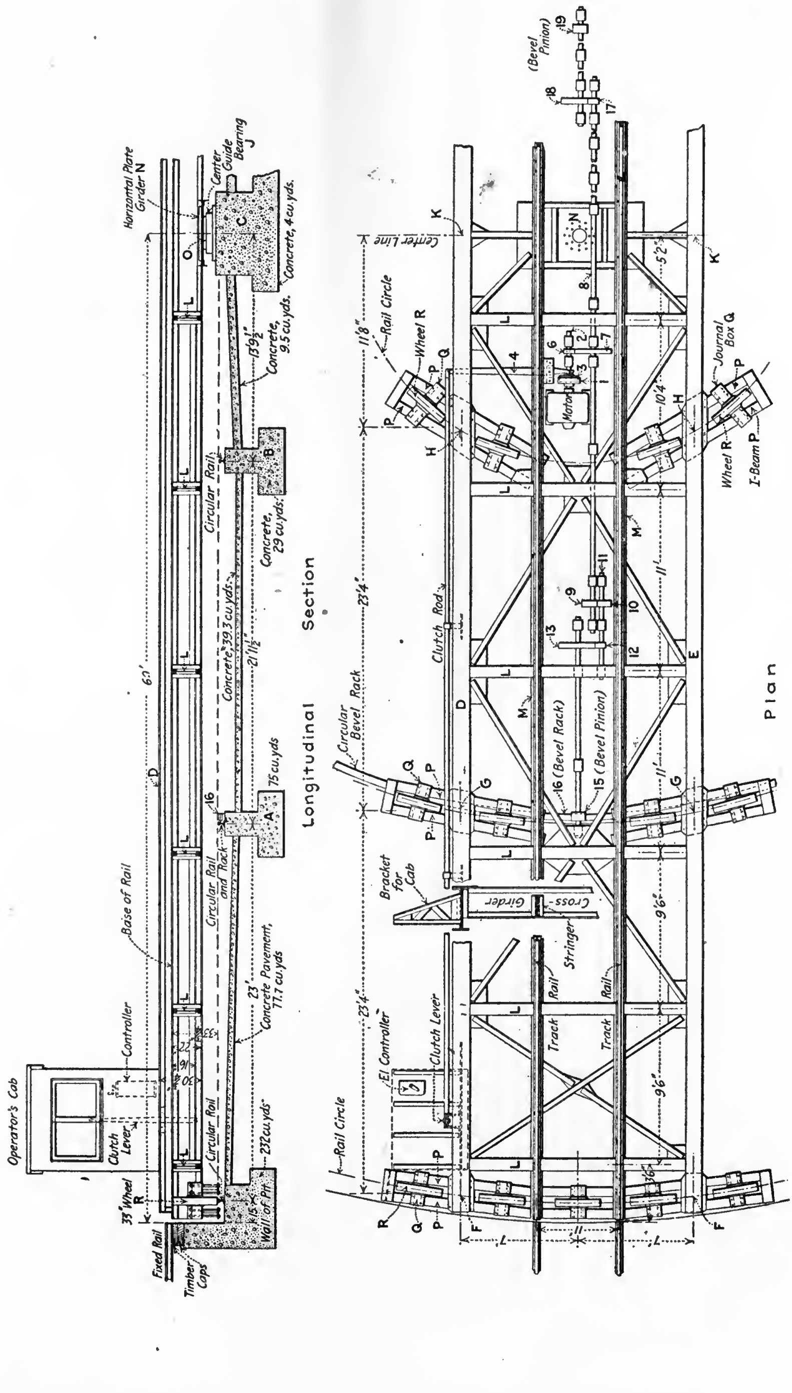


FIG. 108.—120-ft. turntable for Mallet locomotives

Roofs should slope away from the turntable and when steel trusses are used, a ceiling should be placed below them, because steel is rapidly corroded by gases from the engines. Wood or concrete framing is, therefore, preferable. Concrete roofs in very cold climates should be double, or have some other provision for preventing condensation. When slate covering is used, the outer purlins may be slightly convex, and the inner ones concave, to avoid hips and valleys at the trusses, but for tar and gravel roofing curved purlins are unnecessary.

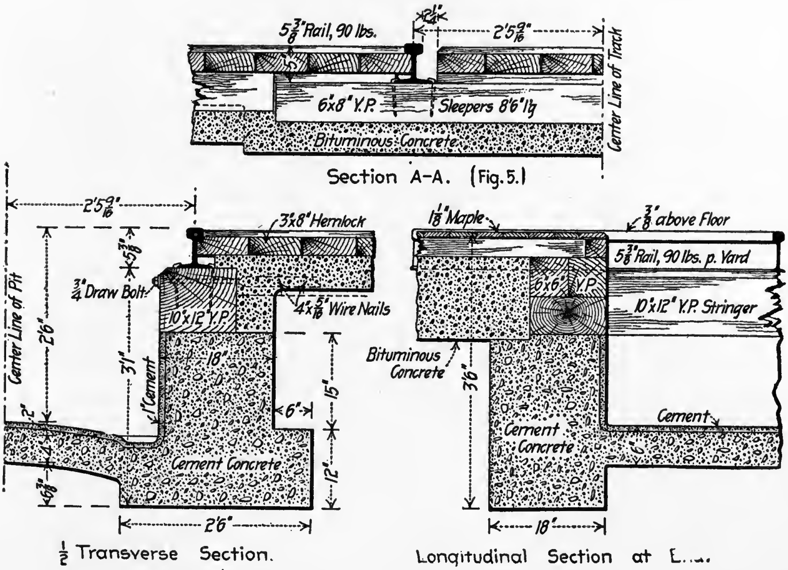


FIG. 109.—Pit details for locomotive shops.

Windows should cover most of the outer wall and they should be balanced on trunnions and operated in clusters by a shaft and wheel. Those over the doors should also be pivoted for the sake of ventilation. Skylights or swing sash on monitor sides may be used, and all interior surfaces above a dark colored dado 5 ft. high, should be whitewashed or painted a light color.

Smoke jacks are sometimes made of asbestos lumber and they should fit down tight over the stacks, and have dampers to stop the draft when not in use. Monitor windows or individual ventilators will supply more ventilation when it is needed. Round houses in cold climates must be heated, preferably by a

hot blast, though steam pipes are sometimes used. Circular round houses complete usually cost from $1300 to $1600 per stall.

Car Shops.—The size and weight of parts made and handled in car shops, necessitate a one-story building with floor on the solid gound. The location for these shops is important, as they usually need a large area of land, not only for spreading out their one-story buildings, but for storing cars and bulky material. A tract just outside of some large city is usually the best, where land values and taxes are low and abundance of labor near at hand. Plenty of extra land should be acquired at first, so there will be room for expansion. In flat or low regions like the prairie states, it is often best to raise the grade from 2 to 4 ft. above the surrounding country, and where natural drainage is not available, sewers may empty into an artificial sump, from which the drainage can be pumped and discharged into the nearest watercourse. An excellent method of arranging the buildings is to place them right and left of a central elevated craneway, crossing transversely all the tracks which enter the successive buildings and the sidings parallel to them. By means of this traveling crane, material from any of the buildings may be loaded on to cars or lifted from them and conveyed to any other track desired. When city water is not obtainable, an underground reservoir must be made and pressure can be secured from an elevated tank 100 ft. in height or more. The new car shops at Winnipeg, Man. (Fig. 110), which are among the finest over built, are laid out as described above, the reservoir being 60 ft. wide, 270 ft. long and 25 ft. deep, capable of holding 2,000,000 gallons, and the elevated tank 125 ft. high will hold 100,000 gallons.

Car Houses.—Buildings for the storage of cars (Fig. 111) contain and cover goods of great value, and as paint, oil and varnish are used about them, precaution should be taken to prevent fire. Walls which face dangerous exposures should be without windows, and the whole building should be divided by fire walls extending 3 ft. above the roof into ground areas of 5000 to 20,000 sq. ft. Openings in the walls should have fire doors. Framing of wood mill construction has been found to be a better fire risk than exposed steel, for the latter collapses quickly under heat. Cornices should be of brick or metal rather than of wood, and windows should have wire glass. Partitions should be fireproof and boiler rooms should be separated from

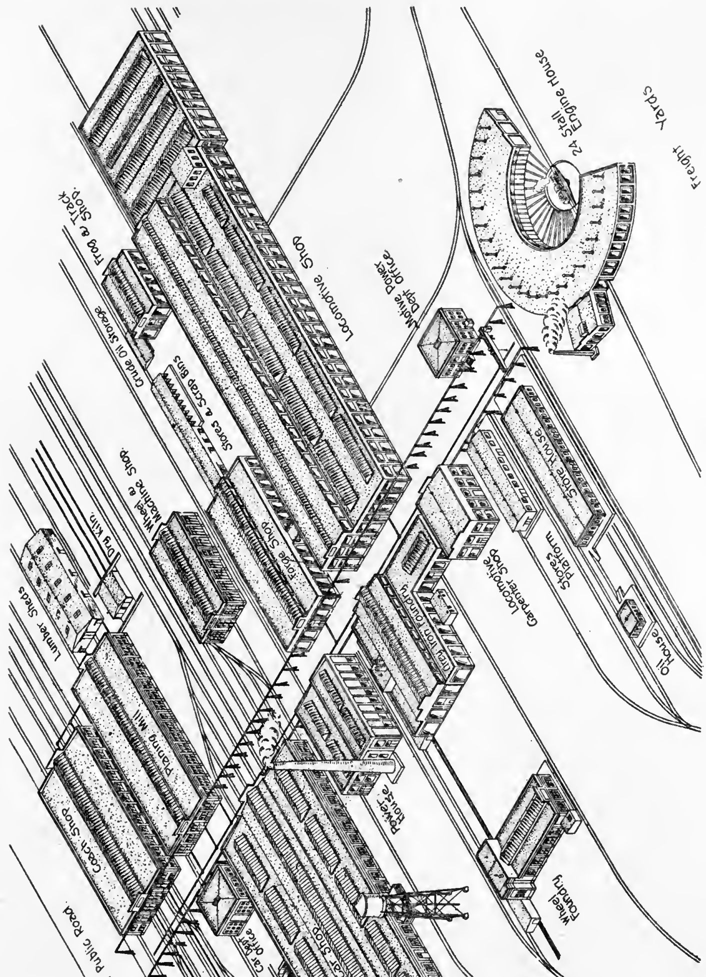


FIG. 110.—New car shops at Winnipeg, Man.

the car shed, the whole plant being protected against fire by a liberal use of fire pails, automatic sprinklers, stand pipes, and chemical extinguishers.

Cotton Mills.—Columns in cotton mills should be spaced 23 ft. apart on centers transversely of the building, and the inside width will, therefore, be 46 ft. for one row of columns, 69 ft. for two rows, and 92 ft. for three rows. For greater convenience, some architects use outside widths of 50, 75, and 100 ft. respectively, and corresponding clear-story heights of 12, 13, and 14 ft.

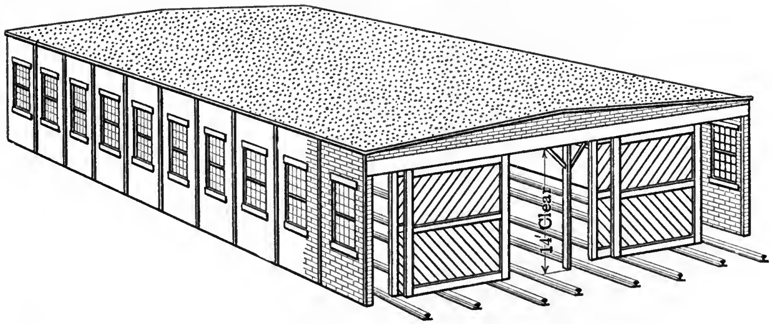


Fig. 111.—A car house.

Power Houses.—Some structural features of power house design may be illustrated, by describing briefly two plants recently designed by the writer, in connection with an electrical engineer in each case.

The first of these (Fig. 112) was for in interurban electric railway company in Ohio. It consists of an engine room 52 by 146 ft. and a boiler room 62 by 146 ft., containing the boilers and a suspended coal bunker 12 by 75 ft. on the outer side of the building, adjoining the railway company's property. The engines and heavy electrical machinery stand on concrete foundations, the space around the foundations beneath the machinery floor being left open and used for basement or cellar storage. The remainder of the engine room floor, not occupied by the engine foundations, is covered with a reinforced concrete slab on steel beams. The steel framing of this floor weighed 22 tons and cost $1100 in place, and the reinforced concrete slab cost $3400 or 56 cents per square foot.

The height under the trusses in both boiler and engine room

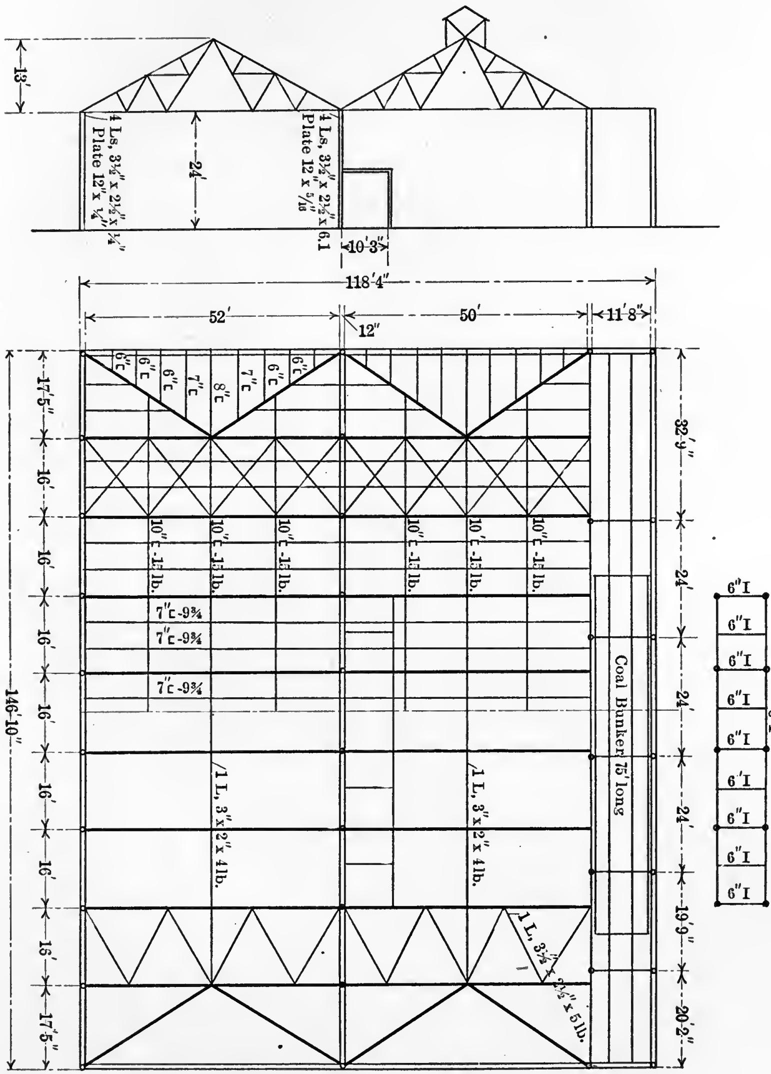


FIG. 112.—A power plant.

is 24 ft. Slate covering is laid on 2-in. plank carried on steel trusses of the Fink type with stiff top chords, placed 16 ft. apart. Jack purlins of 10-in. channels are framed between the trusses to carry 7-in. channel jack rafters, 5 ft. 4 in. apart. On the top of each truss and jack rafter is a 3 by 5 in. wood nailing piece to which the plank is spiked, the joints being parallel with the eave as required for slate covering. Both the boiler and engine room have double pitched roofs, forming a continuous gutter over the center partition wall between the two rooms. At the ends the roofs are hipped, and two panels over each room have stiff-angle bracing in the plane of the bottom chord to keep the trusses properly in line. These two braced panels are united with a line of angles in the center of each span, and in the plane of the rafters also, the same two panels have double rod bracing. The trusses stand on plate and angle columns in the walls and are rigidly knee braced to them. In the engine room is a 10-ton hand traveling crane running on 15-in. beam girders, which are carried on column brackets. The presence of this crane enables the various parts of the engines and machinery to be set or replaced without injuring the trusses. Over the boilers is a continuous ventilator, 48 ft. in length, the sides of which are covered with fixed louvres, and the roof with slate similar to that on the rest of the building. At the rear of the boilers is an elevated platorm 64 ft. in length, framed with 6- and 8-in. beams, and supported on steel columns.

The brick walls serve merely as curtains, because the roof and crane loads are carried directly on the columns. The largest single item of expense in the steel work is the coal bunker, which has a capacity of 200 tons. Coal is hauled up an incline in hopper bottom cars and the coal is emptied from them into the bunkers, the frame of which is strong enough to safely carry the weight of a car holding 50 tons of coal and weighing 15 tons when empty. The tracks and bunker are enclosed and covered with a corrugated iron shed as protection from the weather and the snow. The toe or lower end of the bunker hangs over the front end or doors of the fire box and boilers, and six lines of chutes convey the coal down to automatic stokers. The discharge of coal through these chutes is regulated by means of swinging gates operated by hand. The space below the suspended bunker is used by the workmen in the boiler room. The bunker is lined throughout with $\frac{1}{4}$-in. steel plates, and the bottom is supported

on 9-in. beams, the whole being suspended from two lines of plate girder one on each side, which stand on steel columns. The space between the track stringers is left open for admitting coal from the hopper cars, and the stringers are, therefore, braced over to the plate girders at the sides. The quantities of steel in the various parts, and the cost thereof, are given in the following schedule:

Coal bunker for 50-ton cars	74 tons of steel, cost $5200
Bunker shed	18 tons of steel, cost 2100
Engine-room floor	22 tons of steel, cost 1100
Steel roof frame	65 tons of steel, cost 4500
Traveling crane, 10 tons	1100

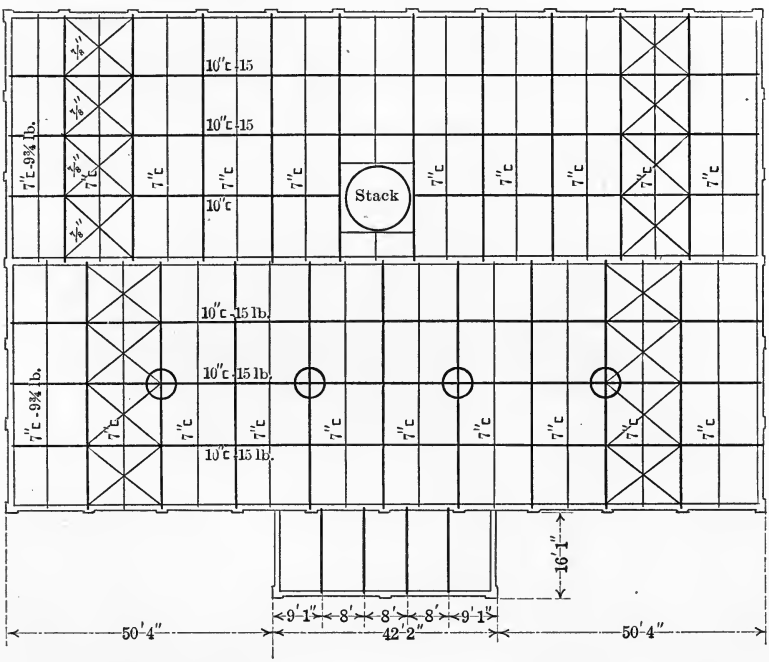


FIG. 113.—Power plant at Huntington, W. Va.

The other power house (Fig. 113) was for an interurban railway in West Virginia. The building is 142 ft. long by 94 ft. wide, and is divided by a brick wall through the middle, making two rooms of equal size. The engine room has a 15-ton hand traveling crane for lifting machinery parts, and the rails on which the crane runs are fastened to the top flange of the crane beams with hook

bolts. This allows adjustment of the rails to suit the distance between the crane wheels. The roof surface of both rooms is covered with 28-in. slate on steel angle purlins, 2 by $1\frac{1}{2}$ by $\frac{3}{16}$ in., spaced 13 in. apart. The boiler room has continuous galvanized iron louvres on the monitor and the engine room, four circular 48-in. galvanized iron ventilators. Between the engine beds in the dynamo room is a system of steel beams carrying corrugated iron arches and concrete floor. The steel work in the floors costs $1400, and the weight of steel in the roof and crane system is 75 tons, and its cost $6200, equivalent to about 45 cents per square foot of floor covered.

CHAPTER XIX

STORAGE POCKETS, AND HOISTING TOWERS

In recent years, the handling of coal in large quantities has led to the construction of several new forms of storage pockets, some of which are herewith illustrated. While these pockets were formerly built of heavy timber that would decay or wear out in a few years, they are now framed largely of steel, and in many cases are also lined with steel plates.

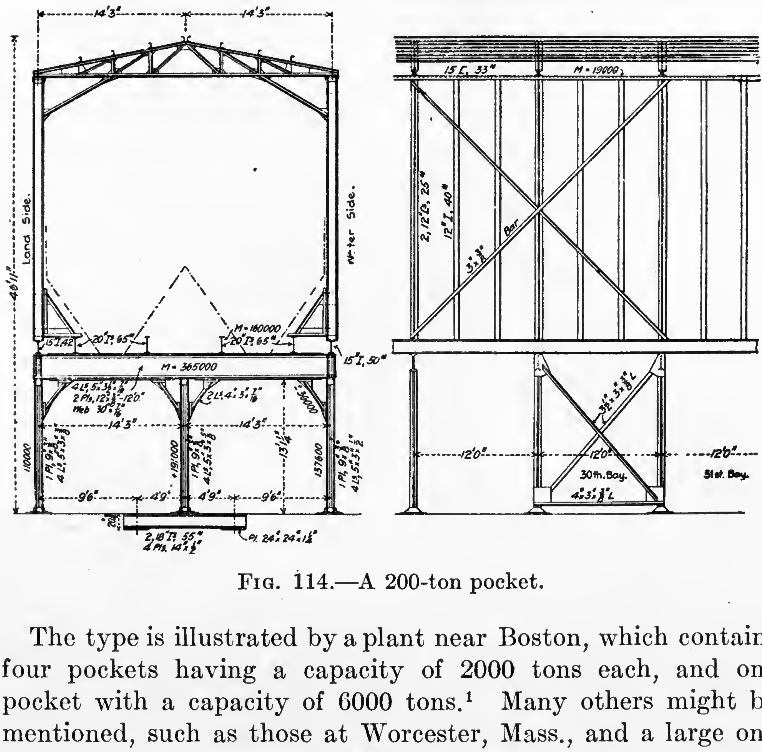


Fig. 114.—A 200-ton pocket.

The type is illustrated by a plant near Boston, which contains four pockets having a capacity of 2000 tons each, and one pocket with a capacity of 6000 tons.[1] Many others might be mentioned, such as those at Worcester, Mass., and a large one designed by the writer at Montreal. The 2000-ton pocket (Fig. 114) mentioned above was 35 ft. wide, 80 ft. long and 72 ft. high to the eave, and coal was conveyed to it by cable cars running on steel trestle work, the cars entering the pocket through

[1] H. G. Tyrrell, in *Railroad Gazette*, Oct. 4, 1901.

openings in the roof. The four pockets were conveniently located to supply coal to the adjoining ovens. They were lined with plank and covered with a galvanized iron roof, and the total weight of steel in one pocket was 510,000 lb., which is equivalent to 255 lb. of steel for every ton of coal stored. The 6000-ton pocket on the dock received coal directly from the vessels. On the top of the pocket above the roof were four steel hoisting towers mounted on wheels, and the position of the towers could be suited to the hatchways in the ships. This pocket was 28½ ft. wide, and 432 ft. long, and stood on a framework of beams and columns, leaving a clear headway of 14 ft. beneath for the passage of cars. It was lined inside with plank which is held in position by 12-in. I beam studs, 4 ft. apart. The sloping hopper sides were of plank on timber blocking. Roof trusses with a 3-in. pitch, placed 12 ft. apart, carried channel iron purlins and corrugated iron covering. The hopper gates were extremely simple but effective. The total quantities of material in the 6000-ton pocket were as follows:

Steel frame	942,000 lb.
One hundred hoppers	39,000 lb.
One hundred hopper gates	17,000 lb.
Corrugated iron	14,500 sq. ft.
Spruce lumber	17,300 ft. B. M.

The total weight of steel corresponds to 166 lb. for every ton of coal stored, which is equal to 3½ lb. of steel for every cubic foot of contents. The roof had small hoppers about 12 ft. apart through which coal was received from the hoisting towers, and the pocket in turn discharged its contents into cars on the three tracks underneath. These tracks were connected with inclined trestle work on which the coal was conveyed to the four smaller oven pockets.

The 4000-ton pocket at Montreal is 28 ft. 8 in. wide, 16½ ft. high and 400 ft. long. Like the one just described, it stands on a frame work of beams and columns, leaving a clear headway of 14 ft. underneath for the passage of cars. In designing it, the following units were used:

Weight of coal	50 lb. per cubic foot
Wind pressure	30 lb. per square foot
Total roof load	40 lb. per square foot
Steel in tension	15,000 lb. per square inch
Steel in compression	12,000 lb. per square inch
Fiber stress in beams	16,000 lb. per square inch

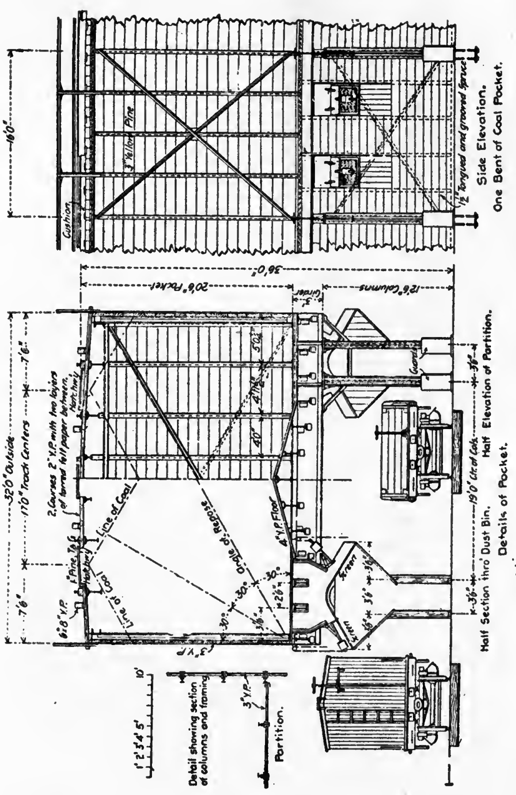
This pocket was divided into thirty-three panels of 12 ft. 1½ in. and was lined throughout with oak plank. The total weight of steel, including the pocket itself and the platform of beams and columns on which it stands, was 666,000 lb. This is equivalent to 166 lb. of steel for every ton of coal stored. Another design for the same pocket, with ¼-in. steel plate lining instead of plank, contained 983,000 lb. of steel, equal to 245 lb. for every ton of coal. These figures do not include in either case, the rails on which the hoisting towers travel, amounting to about 16,000 lb.

The above weights of steel correspond to 3 to 4 lb. per cubic foot of contents. The weight of steel in storage pockets varies almost directly according to the number of tons stored and for plank-lined pockets, is from 160 to 170 lb. per ton of contents, increasing to 240–250 lb. per ton of contents where the pockets have steel lining. If they are designed for the storage of some heavier material such as ore, the above figures will still apply. A large bin designed by the writer for export to South Africa, for the storage of gold ore weighing 100 lb. per cubic foot, contains 7 lb. of steel per cubic foot of bin, or 170 lb. of steel for every ton of ore, the ratio remaining the same as before. These figures give a ready and convenient means of estimating approximately, the quantity of material in these structures.

The coal pocket shown in Fig. 115 is somewhat similar to those previously described, but in this case, the coal is brought to the site by rail instead of water. At one end is a sloping trestle, upon which cars are drawn to the track above the bin, where they are emptied through sliding hoppers into the pocket. The loaded cars are delivered on an adjoining siding and are taken up the inclined trestle by means of a cable pusher, which is operated from an engine plant. The pocket is lined with 3-in. yellow pine and has a plank roof on steel stringers. The side studs are 4 ft. apart and the main panels are 16 ft. each.

Suspension bunkers (Fig. 116) are probably the most economical form in metal, for much heavy beam framing is avoided, and the metal plates which served merely as a lining, in the form described above, now support the load by tension. The type is desirable chiefly when metal plates are required inside. For timber lining, the old style with plank supported on a system of inclined beams, may be found cheaper. Patents on suspension bunkers have been granted, but these do not include all forms of

construction, for similar pockets are made by others without patented features. Metal has the advantage of occupying somewhat smaller space than timber or concrete framing. Pockets of some kind are now almost indispensable for power houses or wherever a large quantity of coal is stored.



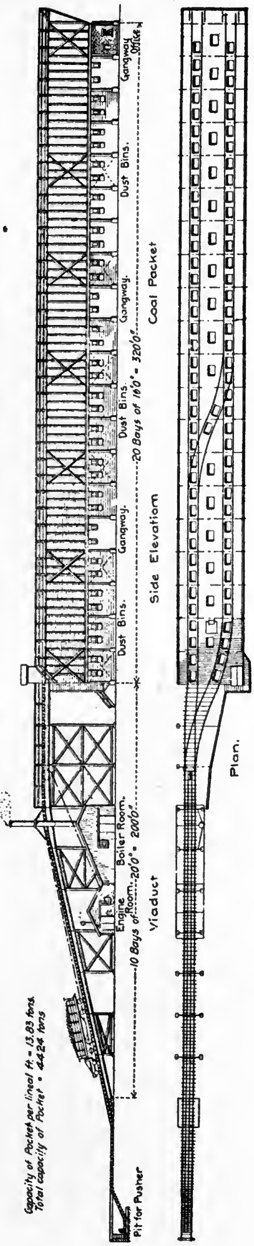


FIG. 115.—Coal pockets.

Concrete coal pockets of 3000 ton capacity or more, cost from \$5.50 to \$7.50 per ton of capacity, and concrete stand pipes, not including the foundations, cost from $2\frac{1}{2}$ to 3 cents per gallon of contents. Combination coal pockets with supports

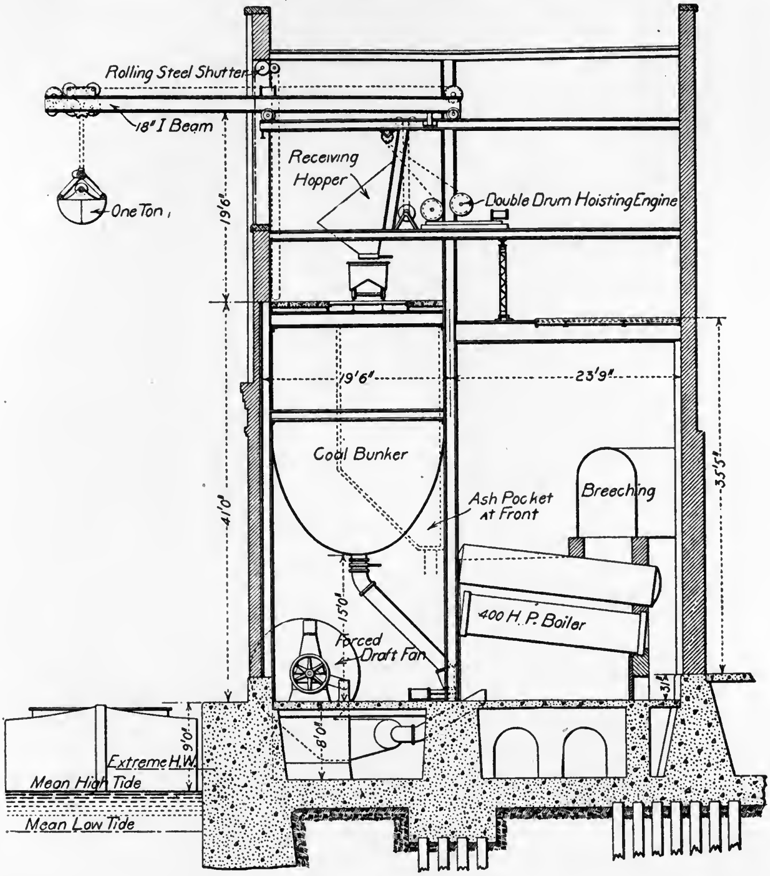


FIG. 116.—Boiler house, showing coal handling equipment. Hecker Flour Mills, New York.

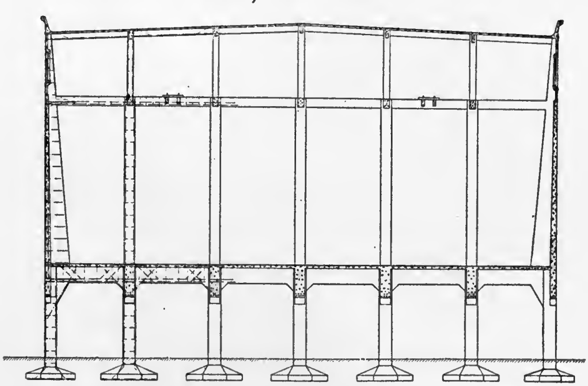


FIG. 117.—A concrete coal pocket.

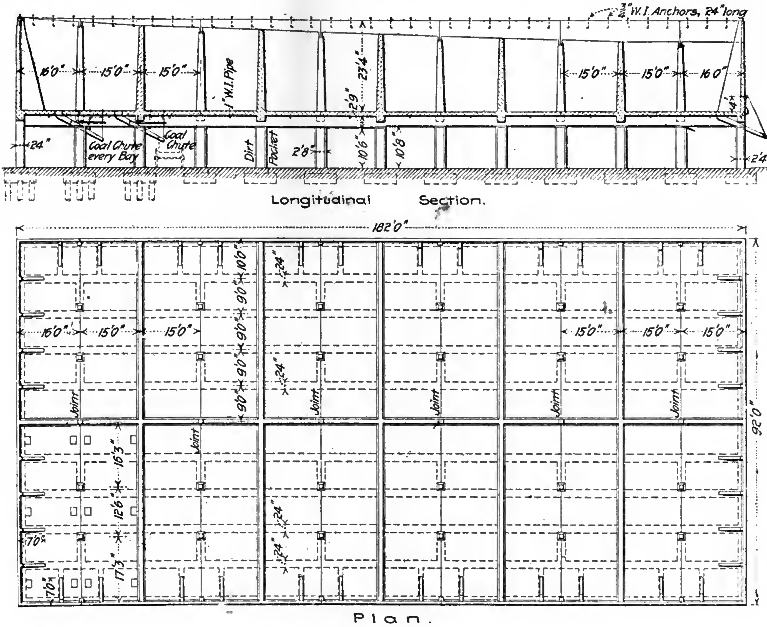


Fig. 118.

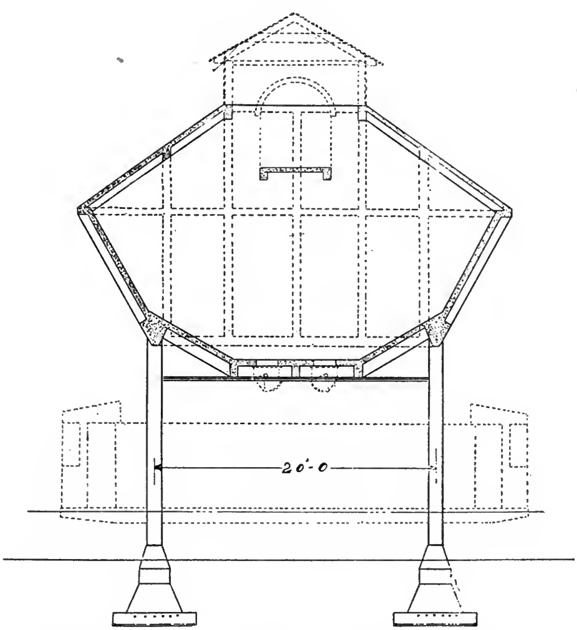


Fig. 119.—Ash pocket at Philadelphia. Philadelphia Rapid Transit Co.

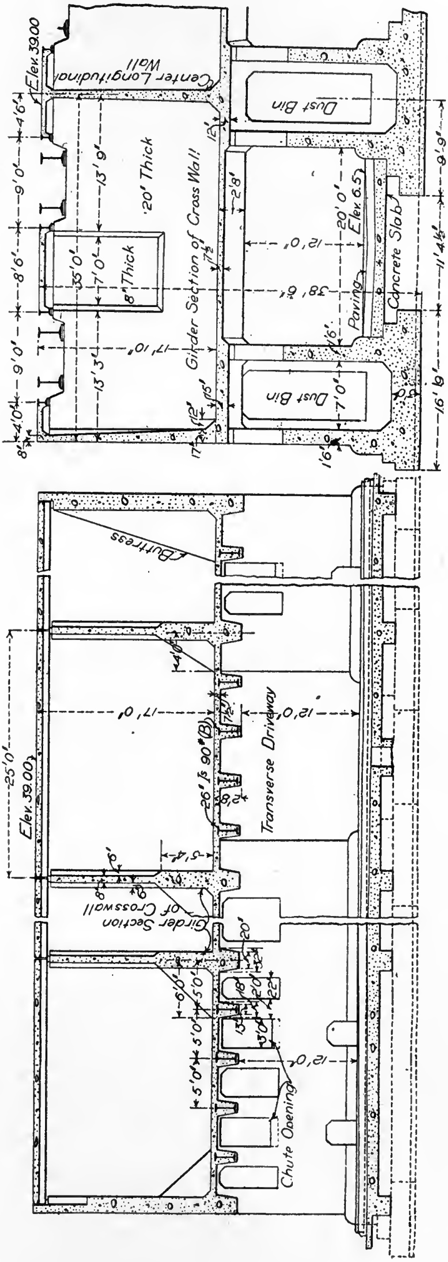

Center Longitudinal Wall
Elev. 39.00
Dust Bin
Girder Section of Cross Wall
20" Thick
8" Thick
Paving
Concrete Slab
Elev. 6.5
Buttress
Transverse Driveway
Girder Section of Crosswall
Chute Opening

FIG. 120.

and floor of concrete and walls of timber, cost about $5 per ton of capacity. Some details of concrete coal pockets are shown in Figs. 117 to 120.

Hoisting Towers.[1]—Coal hoisting towers on the wharfs at seaboard cities were formerly constructed of wood, as were also the pockets to which they deliver coal, but with the introduction of steel, many were afterward built of metal, which, though more expensive than the old style, make a safer and more satisfactory hoisting tower (Fig. 121). They are usually mounted on wheels to travel on the top of a storage pocket, all of those described here being of that type. Other kinds are also used, where the tower

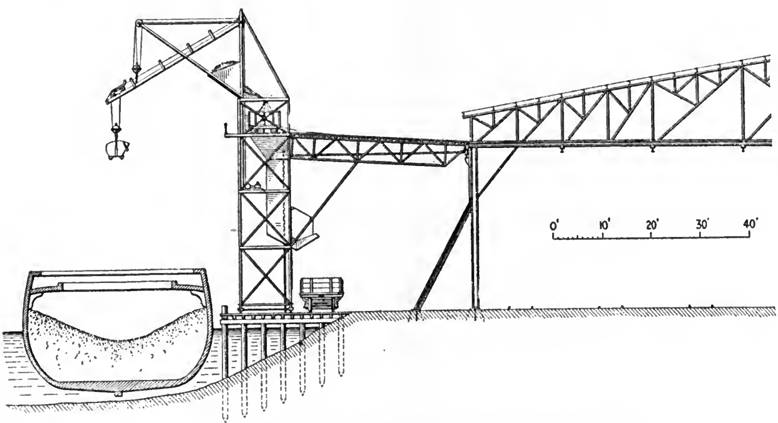


Fig. 121.—Coal handling plant at Dollar Bay.

is combined with a lower house containing the weighing and crushing hopper, the whole being mounted on wheels traveling on the ground. A design of this kind was made by the writer for The Boston Elevated Railroad Company, at the Lincoln Wharf plant.

The type of tower traveling above a storage pocket, is illustrated by one for the Metropolitan Street Railway Company of New York, the frame being 55 ft. high and 24 ft. square at the base, with a single boom 31 ft. in length overhanging the water and boats. The tower has four legs strongly braced together, and the lower part contains an engine room from which the hoisting is controlled. The engine house is roofed over and enclosed on the sides with corrugated iron, having windows enough to admit

[1] H. G. Tyrrell, in *Engineering News*, May 30, 1901.

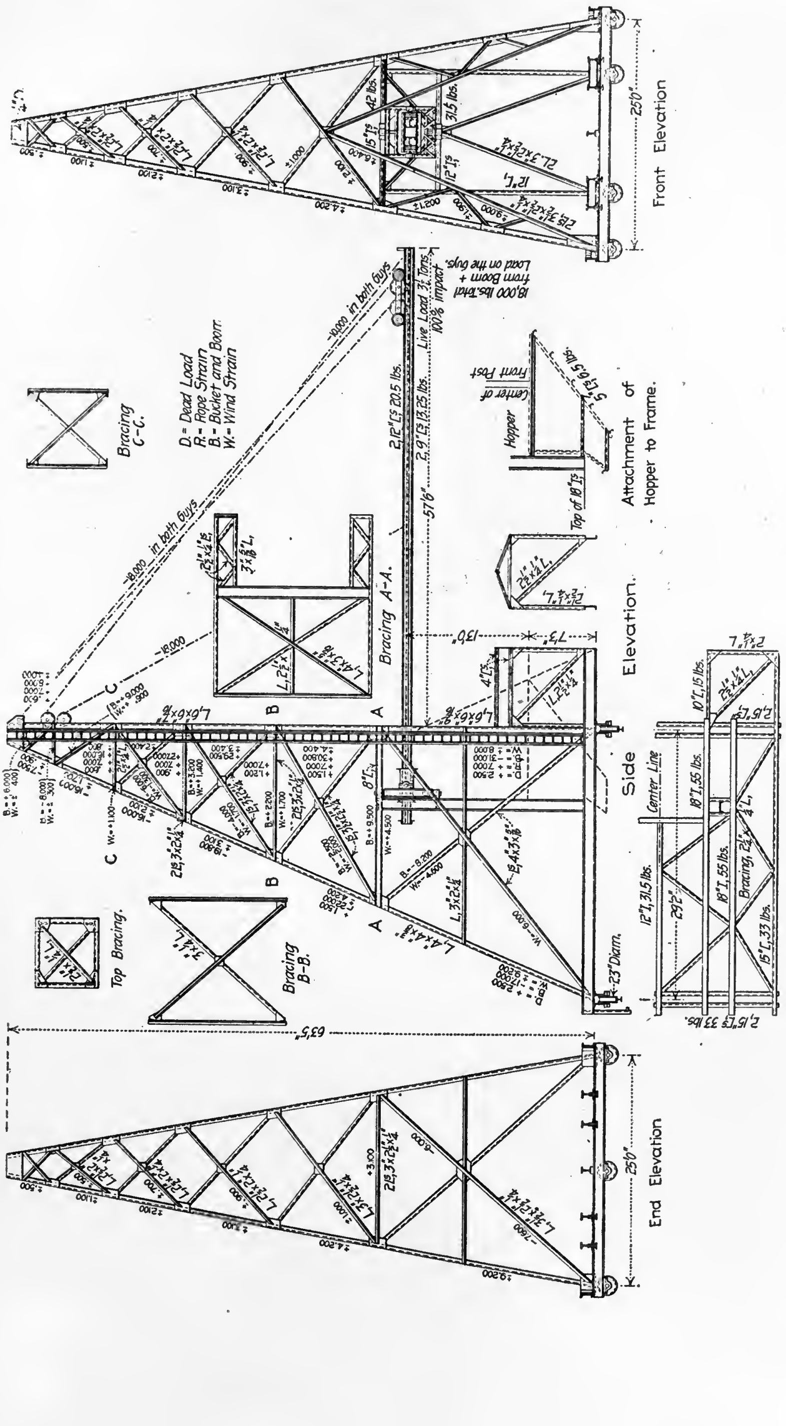


FIG. 122.—Coal hoisting tower for the Dominion Coal Co., Montreal.

the light. The crushers are supported on framing about 8 ft. below the engine room floor. The hopper is of $\frac{5}{16}$-in. plate with a frame of angle and channel iron. The tower was designed to carry a live load of three tons at the end of the boom with an allowance of 100 per cent. for impact. It contains 18 tons of steel and cost, including floor, roof and sides, $2250.

Another tower, somewhat similar to the last, designed by the writer for the Dominion Coal Company at Montreal, has a height of 63 ft. and a boom 51 ft. long, with a base 29 ft. long and 25 ft. wide. The boom is swiveled at the rear end and was proportioned for a live load of $3\frac{1}{2}$ tons, with provision of 100 per cent. for impact. The floor is very heavy, being made of 12- and 18-in. steel beams. It has a ladder on one side, enabling the operator to inspect and oil the bearings at the tower top. The total assumed load at the end of the boom is 18,000 lb. The tower is mounted on seven wheels and has a safety clamp at the rear to prevent tipping. It contains 27 tons of steel besides the trolley rope and operating machinery. The hopper is lined with plank and the house enclosed with sheathing. (Fig. 122.)

CHAPTER XX

FACTORY HEATING

Heating may be done by the use of direct or exhaust steam passing through coils of pipe, or by warm air in large quantities forced by fans through ducts to different parts of the shop. As the latter type of heating is the one best adapted to shops and factories it is described at greatest length in the following pages.

In the heating and ventilating of industrial buildings, economy is of prime importance, and it is from this standpoint that the acceptance or rejection of the fan system must be decided, though sanitation even from a mercenary consideration must not be disregarded, for upon the comfort and well being of the workmen must their efficiency and contentment depend.

Apparatus for Fan System.—A heating system is composed of three essential elements—the heater, the fan and the distribut-

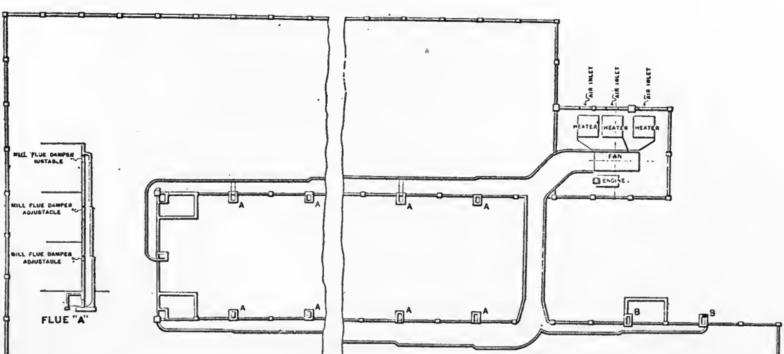


Fig. 123.—Fan system in automobile plant of George M. Pierce, Buffalo.

ing ducts. The heater consists of rows of vertical 1-in. wrought-iron pipes, screwed into a manifold cast-iron base which is divided into separate units or sections. The coils are tightly enclosed on

the top and sides by sheet steel casing. The air is drawn or forced through between the pipes by means of a centrifugal fan which connects with the heater casing. The fan should be amply large and should be driven at sufficient speed to produce an air velocity of about 1200 ft. per minute through the clear area of the coils. This velocity is an important condition since the effectiveness of the coils is largely dependent upon it. The increased efficiency of the heating surface from this cause is so great that only from one-third to one-fifth as much surface is required with the fan system as with direct radiation. Further, as will be shown later, the heat is so applied and distributed that it is far more thoroughly utilized than in ordinary radiation.

Heat Losses.—Heat losses occur in a building from two causes. First, by the direct transmission of heat through the walls and exterior surfaces of the building, and second, by the infiltration of cold air from without. In designing a heating plant, the first of these losses may be very accurately determined by referring to tables showing the amount of heat radiated under different conditions through various thicknesses of walls, windows, doors, floors, etc. The heat loss through infiltration differs so greatly in various sizes and constructions of buildings, that no absolute rule can be given. The allowance to be made for heat loss is necessarily the result of experience and of careful tests of previous installation.

Infiltration or leakage is produced by the unbalanced pressure of the column of heated air within the building, and that of the cold air without. The action is, in principle, precisely like that of a chimney. The difference in pressure produced can be measured in inches of water, and increases in direct proportion to the difference in temperature between the air within the building and that without. Since the flow of air is proportional to the square root of the pressure, that amount of air entering or leaving the building through leakage will be in proportion to the square root of the difference of temperature. The effect of this leakage is as evident in theory as it is noticeable in practice. The air which escapes from the building is naturally the very hottest and, therefore, has not had its heat fully utilized, while that which enters along the floor chills the air at the lower part of the building perceptibly, forming a cold layer of air which cannot be removed except by a positive circulation or diffusion with heated air such as may be secured by the fan system. In

large machine shops and foundries, this layer of cold air may frequently be found to extend from 4 to 6 ft. above the floor, while overhead there is a volume of overheated air which, if utilized, would heat the entire building. The most effective remedy for this evil is to maintain a slight pressure within the building by means of a fan which takes a portion of its air from without, thereby causing a displacement and removal of cold air.

Fan System and Direct Radiation Compared.—In either fan or direct radiation systems, difficulty is likely to be experienced from the rise of heated air which forms a stratum just beneath the roof. In machine shops and foundries, owing to their heights and to the great amount of skylight which is usually provided, the loss occasioned by this action of the heated air may be considerable, and its prevention is a serious problem. In direct radiation, where the air currents are wholly due to the difference in temperature, the attendant loss, which is relatively great, is unavoidable. Practically, the only way in which this heated air can be made use of is by placing the coils next to the wall near the floor, and allowing the heated currents to pass upward along the walls, but even this method is wasteful from the fact that it heats the walls unduly, causing a loss which may usually be estimated as great as 25 per cent. of the total heat supply. Pipes near the walls fail to properly distribute the heat and the central part of a building may be much cooler than the sides. The fan system, however, since the method of distributing the air is entirely mechanical, affords an opportunity for utilizing its heating effects to the very best advantage. Various methods of distribution have been devised with fan system whereby the effect of a rising current of heated air is almost entirely avoided. These systems in general, depend upon securing diffusion of the heated air along or near the floor line.

Systems of Air Supply.—The method of distributing the air in the building is a consideration of chief importance. The usual methods of supplying heated air are: First, to take the air entirely from without, and force it directly into the building through distributing ducts. This method is generally known as the Plenum System. The pressure produced in the building causes a continuous exit of air from the building, either through the natural openings as is usually the case in factories, or through special vent openings provided for the purpose. This effectually prevents the entrance of cold air from without.

A second and more common method for shop buildings where forced ventilation is not a necessity, is to draw the supply of air entirely from within the building and again force it through the distributing ducts, causing a continuous circulation of the air within the building. This often has an advantage over the plenum system in that all the heat supplied to the air is effective for heating. This method is especially suitable in very cold climates but can be used only where gas, fumes, or smoke are not generated inside the shop.

An ideal arrangement is a combination of the plenum and return systems, and this should be used wherever possible. By

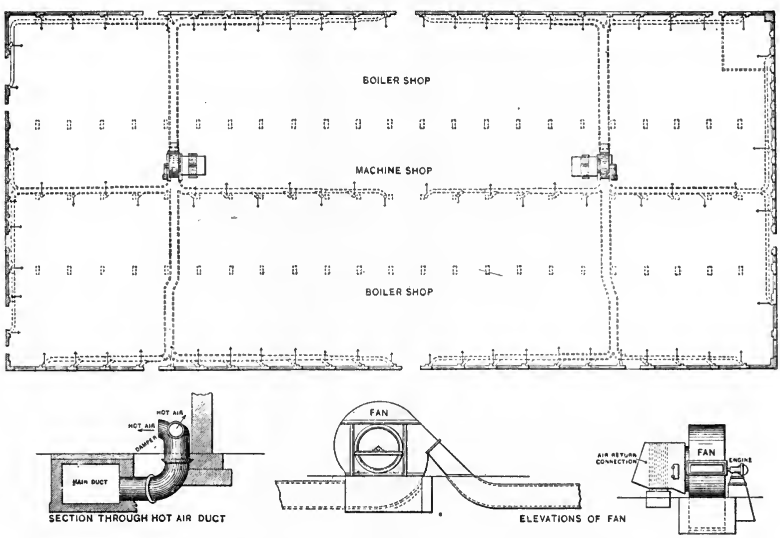


FIG. 124.—Fan system in railway machine shop at Collinwood, Ohio.

this method, the greater portion of the air is returned to the apparatus, but sufficient air is continuously taken from without through a fresh air connection to create a plenum within the building and prevent the inward leakage of cold air along the floor. In this manner the natural leakage is supplied, not by inflow of cold air through crevices around the doors and windows, but by air passed through the apparatus and heated to an effective degree. This combination has been found by tests to be more economical than air returned alone. The proper amount of air to be introduced from without is determined by securing

a point where the noticeable inward flow of air around the doors or windows ceases. If the plenum is carried beyond this point, there will be a loss due to unnecessary heating of the outdoor air. Air should always be supplied at the right degree of humidity in order to prevent occupants of the building from taking cold. This can best be done in the air washing process. The heating apparatus and fans should be placed at one side of the building somewhere near the center of its length, but nearest to that end which may at some future time be extended.

Systems of Air Distribution.—There are several systems of distributing the heated supply of air. A method usual in public and office buildings and sometimes employed in factories, is the vertical duct system by which the air is admitted through vertical ducts or flues built into the walls and opening at a point about 8 ft. above the floor. Suitable openings are supplied at the floor line for the air that is forced out. By this method, the heated air is continually forced downward as it cools, and the cold air is always removed at the floor line. In some cases ducts in the walls have been lined with hollow brick, but later experience proved this to be not only unnecessary but undesirable.

A method of distribution quite similar to this is one where the air is first blown into brick ducts underneath the floor. From these ducts vertical galvanized iron risers are arranged along the wall. These are placed so as to blow downward and away from the wall at a height of about 8 ft. from the floor. These outlets should be adjustable so that, in case too direct a draft is caused in any portion of the building, the outlet can be turned in some other direction where the air current will not be objectionable.

This system is sometimes modified by placing the outlets close to the floor and blowing downward directly along the floor. This secures a perfect diffusion of the heated air at the floor line, and avoids any draft.

Excellent results can be secured by the use of overhead piping, provided it is not placed at too great a distance from the floor The chief advantage of the overhead system is the saving in first cost, since on account of the high temperature and velocity of air in the distributing pipes, a great amount of heat can be transferred with a very small amount of material. The cost of the galvanized iron distributing system of air ducts is relatively small. Circular pipes have less perimeter for a given area than square ones and, therefore, require less material to make them.

They should always be galvanized. The best results are secured with outlets from 12 to 18 ft. above the floor line. Above this height it is preferable to use drop pipes extending downward along the columns, where they will not interfere with traveling cranes. Such an arrangement of overhead piping is very frequently employed in foundries, while in large machine shops underground ducts are nearly always preferable. The discharge openings should be not less than 5 in. in diameter and the aggregate area of all the openings should give at least 6 sq. in. for each 1000 cu. ft. of building contents, so that air within the building may be changed two to three times every hour. Outlets should be about 30 ft. apart, and the total area of all the openings should be about 25 per cent. greater than the area of the main supply pipe. Bends in ducts or branches from them should always be made with gradual curves rather than sharp angles to avoid obstructing the flow of air.

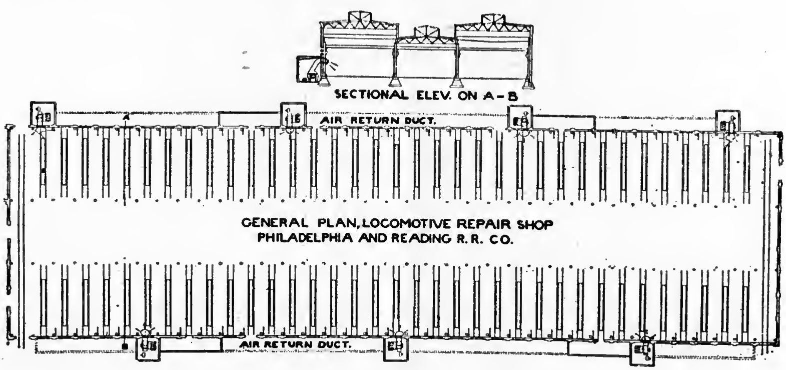


Fig. 125.—Heating plant in railway machine shop.

Another system which has proved very satisfactory is that in which a distributing air return duct is employed. This approaches very closely in principle to the plenum system used in public buildings and is a combination of both plenum and exhaust systems. This may be best described by referring to the heating plant at the Philadelphia and Reading Railroad shops at Reading (Fig. 125). In this instance several separate sets of apparatus have been provided, placed in small fan houses built at intervals at either side of the building. The peculiar feature in this installation is that no distributing ducts or piping for the heated air are used. The air is blown directly into the building

at about 8 or 10 ft. above the floor through an outlet branching in three directions. The distribution is affected entirely by the return vent ducts which are placed at frequent intervals along the walls. These open into large return air tunnels which are provided on either side of the building, and serve the additional purpose of affording a convenient place for locating steam and water mains, and also electric light and power cables.

In many instances an elaborate distribution is impracticable or undesirable. In such cases a centrally located discharge pipe may be used. From this point the air is blown in all directions, and a circulation is produced by an exhaust connection to the fan inlet. In such instances very effective heating has been secured even where it was required to blow the air long distances.

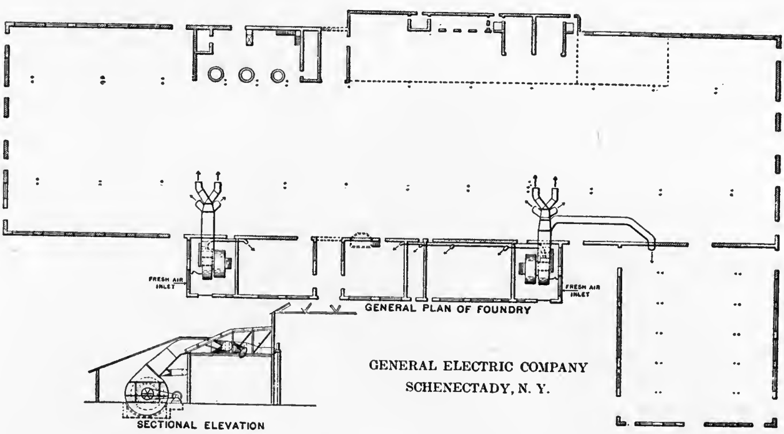


FIG. 126.—Foundry heating apparatus with only small amount of distributing pipe.

A good example of such a system may be found in the foundry building (Fig. 126) of the General Electric Company at Schenectady, which is one of the largest in the world and is heated in a satisfactory manner with a few large branch outlets. Since the plant was installed, a large addition has been made. This portion is heated by a branch outlet situated 200 ft. from the further end which shows how thorough distribution may be secured by forced circulation.

The works of the Warren Featherbone Company at Three Oaks, Michigan, gives a typical installation of the fan system to a group of scattered buildings, and is remarkable chiefly for the distance

to which the heated air is transmitted from the apparatus to the various buildings. The hot air piping is carried entirely out of doors, and is protected by a wood boxing filled with sawdust. The loss of temperature in passing through this piping is determined by test to be only 5 degrees, which is remarkably small considering the length and exposure of the piping. It has the advantage of a central location of apparatus near the power house, thus utilizing the exhaust steam without long and expensive steam piping, and minimizing the amount of attention required.

Advantages of the Fan System.—It has been shown that a most important source of economy with the fan system lies in the ability to secure a perfect distribution and diffusion of heat and by the production of a plenum, preventing the cold air from entering the building and settling along the floors. Besides this the temperature is much more easily regulated with the fan system, with separately controlled heater sections, than with direct radiation, and thus a great loss which frequently occurs, due to overheating, is prevented.

Utilization of Waste Heat.—Another point in economy is the utilization of waste heat. By far the most common form of waste heat is from steam engines and other steam driven machinery. The ordinary simple engine running non-condensing has a water rate of about 32 lb. per horse-power and uses only 20 per cent. of the total heat of steam in work radiation, leaving a remainder of 80 per cent. available for the use in heating apparatus, which would otherwise be wasted. As the mean effective pressure in the ordinary engine cylinder may be placed at 40 lb. per square inch, an increase of 1 lb. per square inch in back pressure reduces the effective horse-power of the engine $2\frac{1}{2}$ per cent. and correspondingly increases the cost of the power production. In a compound engine the effect of back pressure is still more noticeable since the mean effective pressure referred to the low pressure cylinder may be placed at about 30 lb. per square inch; each pound of back pressure therefore reduces the power of the engine $3\frac{1}{3}$ per cent. It is therefore evidently unprofitable to use a system which will greatly increase the back pressure of the engine. The ordinary system of direct radiation used in shop buildings usually cannot be operated successfully without placing a back pressure upon the engine which is prohibitory. On the other hand, the fan system heater is designated

to circulate steam at very low pressure and can be operated successfully with ½-lb. pressure on the engine.

Air Economizers.—An air economizer is employed to great advantage at the plant of the Cheboygan Paper Company, where 900 boiler horse-power of live and exhaust steam is required in heating the rolls and beaters. The building is heated by the fan system in connection with an air economizer, and a system of mechanical draft. This makes nearly all the exhaust steam of the plant available for use in the rolls and increases the economy and heating capacity of the boilers from 10 to 15 per cent. This system illustrates another method of removal of the steam directly from the machinery by the use of hoods and disk fans. Sufficient hot air must be introduced into the building to take the place of the air removed, and to keep the building warm, otherwise condensation would occur. The above system of heating with air economizer is in successful operation in many places.

Heating with Exhaust Steam.—Where condensing engines are used, it is sometimes questioned whether it is cheaper to run them non-condensing and use exhaust steam for heating, or to operate condensing and use live steam for heating purposes. The water rate of a compound Corliss engine at full load is about 20 lb. per horse-power non-condensing, and 14 lb. condensing, so that the water rate is 30 per cent. less when running condensing than when non-condensing. The amount of heat available in the exhaust steam when running non-condensing is about 80 per cent. Hence, we see that the saving of steam running condensing is only 6 lb. per horse-power while the heat available in the exhaust steam is 16 lb. per horse-power and therefore a saving of 10 lb. of steam per horse-power could be made by operating non-condensing and using the steam in the heater if all the steam available could be used. There would also be saving so long as more than 38 per cent. of exhaust steam was utilized in the heater. With less economical engines, the saving made by running non-condensing and utilizing the exhaust steam is greater.

With the steam turbine, the water rate increases very much more rapidly with the decrease in vacuum (as shown by an increase in the number of inches registered on the vacuum gauge) than with a steam engine. A steam turbine which, with 28 in. of vacuum, has a water rate of 20 lb. of steam per kilowatt hour at full load when running non-condensing requires 50 lb. of steam per kilowatt hour at full load. Hence the use of exhaust from

turbines without a vacuum is economical when the heating requirements are more than 60 per cent. of the steam consumption of the turbine running non-condensing.

Other sources of waste heat have been utilized to great advantage by means of an air economizer in connection with the fan system of heating, and mechanical draft, and the waste gases from the boilers, burning kilns, gas engines, etc. The heat of these gases is being successfully used in many places for both heating and drying purposes. By this system it is possible to reduce the temperature of the boiler flue gases from 550 to 250 degrees, thereby increasing the heating capacity and economy of the boilers approximately 15 per cent. The saving affected by the utilization of these sources of waste heat frequently pays for the cost of installation, in one season's operation.

Flexibility of Operation.—The fan system possesses a great advantage over direct radiation systems in its flexibility of operation. With direct radiation a building heats up very slowly, and it is usually necessary to maintain a normal temperature all night in order to have it sufficiently warm in the morning. On the other hand, the fan system with the proper amount of reserve, can heat a building up in a short time. This allows the building to be cooled down during the night to just above freezing-point, say an average temperature of 35 to 40 degrees.

First Cost.—Besides these advantages in economy over direct radiation, there is usually a considerable advantage in first cost in favor of the fan system. This is due to the compactness of the system, requiring fewer connections and shorter lengths of steam mains, but more particularly to the great saving in amount of radiating surface required owing to its greater effectiveness in the fan system. A determining factor in the rate of heat transmission of any heating surface is the velocity of air over that surface. This can be shown by curves or chart, exhibiting the relation between air velocities and heat transmission. In direct radiation, the heat is transmitted by convection currents and radiation only, while with the fan system an air velocity over the coils of 1200 to 1500 ft. per minute is usual; the former transmits only from 2 to 2.6 B.T.U. per square foot per hour per degree difference in temperature, while the fan system heater transmits from 11.8 to 13.4 B.T.U. per square foot per hour, per degree difference in temperature, or more than five times as much as direct radiation. Hence a correspondingly smaller

amount of radiating surface may be used, which more than offsets the additional cost of fan, engine and hot-air piping.

The chief points of superiority of the fan system may be summarized as follows:

1. Good ventilation regardless of exterior conditions.
2. Uniform and proper distribution of heat.
3. High efficiency of heating surface.
4. Greatest economy in operation.
5. Utilization of exhaust steam.
6. Prevention of cold drafts from without by production of a plenum.
7. Independent regulation of heating and ventilating effects.
8. Great flexibility in operation to suit varying conditions.
9. Ease of control which prevents overheating.
10. Compactness with economy of space and low cost of steam connections.
11. Good drainage, with few repairs.
12. Low cost of installation.
13. Apparatus capable of removal to another plant if required.

The Vacuum System.—The evident and growing need of a heating system which will utilize the exhaust from condensing engines and steam turbines under a considerable vacuum has led to the introduction of the vacuum fan system of heating. This system competes in no way with others, but simplifies the method of application and enables vacuum to be secured, otherwise impossible. It insures at all times a perfect circulation of the steam in the heater coils and maximum economy when operating with the exhaust from engines or turbines operating with high vacuum. The system is particularly adapted to the successful operation of several heaters widely separated and well removed from the central source of steam.

Roundhouse Installation.—The application of the fan system is advantageous in the heating and ventilating of locomotive roundhouses. These are especially difficult to heat on account of the large volume of warm air carried off through the open smoke jacks which act as ventilators. A great deal of heat is absorbed, too, in the melting of the snow and ice on the locomotives and in the evaporation of the moisture thus produced. Ample ventilation is required to remove the smoke and steam produced by the engine and this necessarily consumes much heat. The air is drawn directly from out of doors and after passing

through the coils of the heater, is distributed by a system of underground ducts to the different stalls where it is discharged into the pits directly beneath the engine. Often the outlets in the pits are provided with adjustable elbows and dampers so that the blast of hot air can be directed against any desired part of the engine or closed off entirely. More frequently, however, outlets are allowed to remain open at all times. By blowing the hot air directly underneath the engine, the snow and ice are melted in the shortest possible time and the moisture is absorbed by the hot, dry air wih great avidity. The distribution of the heat at the floor line places it where needed and permits it to be utilized to the fullest extent before the air passes out of the building. As the air is taken entirely from outdoors, the necessary ventilation is secured at all times and a plenum is produced within, which tends to counteract the cold drafts occasioned by the frequent opening of the doors.

Application to Textile Mills.—In textile mills there is the additional problem of securing proper humidity together with ventilation. Operators in textile mills have long appreciated the importance of correct humidity and temperature conditions in the spinning and weaving processes. While these requirements were well understood, no entirely satisfactory or adequate method has heretofore been introduced for securing the desired effect. These conditions which have such an important bearing upon the textile processes are: First, the humidity which is naturally quite insufficient for the best results during the greater part of the year, especially in the cold weather of winter and in the hot, dry weather of summer. Second, the temperature which should be maintained at from 70 to 75°, requires special heating in winter and cooling if possible in summer when the high outside temperature augmented by the weaving and spinning machinery becomes a great detriment. Third, ventilation, which, though not so important as the others commercially, is imperatively demanded from a humanitarian point of view where so many women and children are required to work in a comparatively small space. In order that the best results may be secured in a cotton mill, the air must contain a percentage of moisture, which can most easily be provided by blowing air into the shop charged with the proper amount. A dry atmosphere is detrimental to the manufacture of cotton goods in that it causes a great deal of electricity which makes the fibers separate,

but when a certain amount of humidity exists, the fiber becomes more adhesive and pliant, and consequently the yarn becomes smoother, stronger and softer.

The demand for a betterment of these conditions has led to recent improvements in ventilating and heating textile mills, one of the very latest improvements in this direction is a system for humidifying, ventilating and heating. The apparatus is composed of five essential elements, the tempering coils, the humidifier, the heater, fan, and the system of air ducts.

The air is first drawn through a series of tempering coils controlled by the proper temperature for humidifying: thence, it is drawn by the fan through the humidifier and forced through heater coils and by-pass where sufficient heat is imparted to it to maintain the desired temperatures in a room. By this arrangement the control of humidity is absolute and may be varied at will between any desired limits. The mechanism is exceedingly simple and relatively inexpensive. The temperature in the room is under absolute control without affecting the volume of ventilation. A uniformity of temperature and humidity is maintained. When the air is taken from outdoors it is washed and purified as well as humidified. In this way fresh air is constantly supplied, enabling the operatives to work in a pure healthful atmosphere under all conditions of weather.

Fan System in Paper Mills.—In cold weather great trouble is usually experienced in paper mills from the condensation produced from the moisture laden air coming in contact with the cold roof and walls. This condensation not only drops back on the dry paper producing blisters, and thus injuring the product, but causes the roof boards and timbers to rot out quickly. The most practical and satisfactory method yet devised is to blow hot air into the building just over the machines. Heated air is thrown against the roof and walls by a set of outlets, while another set of outlets is discharging air against the machines. The first set of outlets keeps the roof warm while the air from the second set diffuses the steam remaining away from the machines and dissipates it. Air supplied is always drawn from without, and an exit for the moisture laden air is provided by louvres or ventilators in the roof. This insures a rapid absorption and removal of the atmosphere.

Fan System in Paint Shops.—In paint shops it is desirable to dry paint rapidly and it is necessary to avoid drafts which agitate

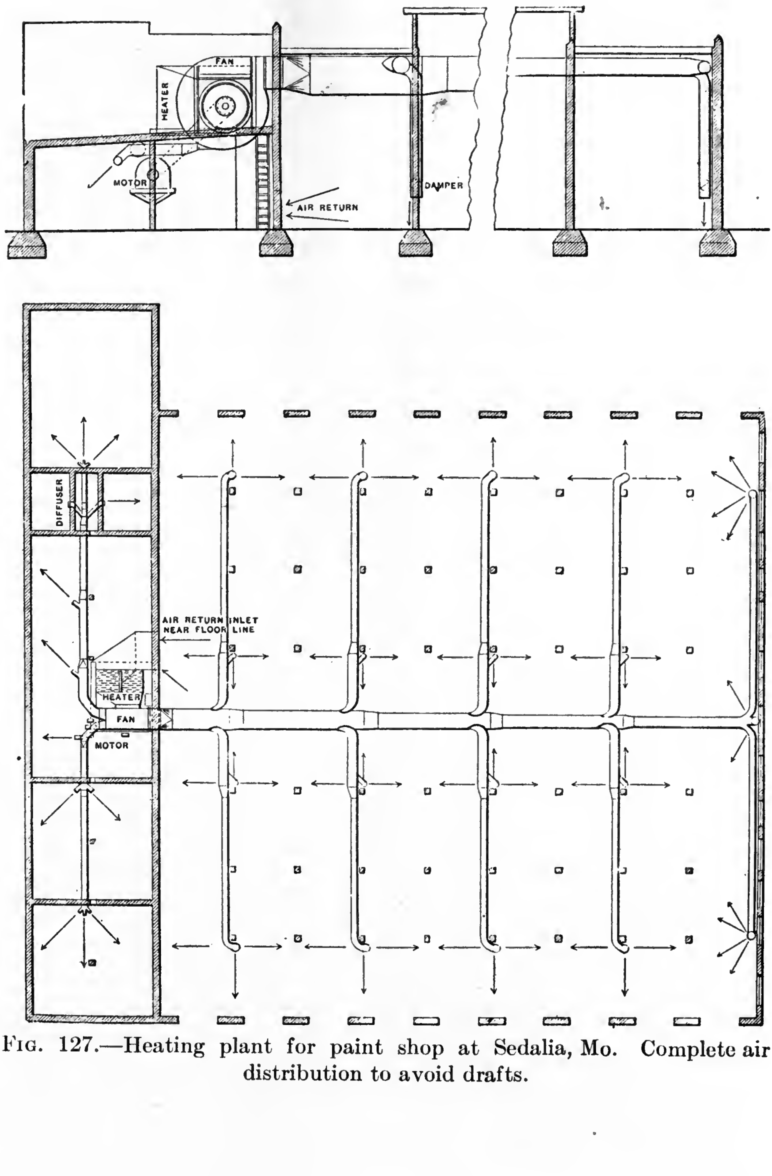


FIG. 127.—Heating plant for paint shop at Sedalia, Mo. Complete air distribution to avoid drafts.

dust and blow it about the building. With the fan system the former results are obtained by the introduction of dry air from without, and the latter is avoided by the use of unusually low air velocities and special arrangement of ducts. In the fan system of paint shop heating, a combined plenum and exhaust system is frequently employed with most gratifying results. The air may be discharged through an overhead system at low velocities. A downward circulation is produced and all cold or moist air is removed at the floor line by exhausting a portion of the air through underground ducts opening into the pit under the cars. This system avoids all disturbing air currents and affords a perfect distribution of the heated air. In locations where a great deal of smoke and dust prevails, a system of air purifying may be used to advantage. The rapidity of drying secured by the fan system far exceeds that obtained by any other method, owing to the frequent renewal of the air and its consequent greater drying effect (Fig. 127).

Steam Heating.—Heating by direct radiation is usually slow on account of the long lines of pipes, unless a vacuum circulation is installed, and steam pipes are likely to leak and fill with condensation. A common rule, known as "the 222 formulæ" for finding the amount of radiation surface, is to supply 1 sq. ft. of radiation for every 2 sq. ft. of window, 20 sq. ft. of exterior wall, and 200 cu. ft. of building contents. The sum of these three quotients will be the total required area of radiation surface.

Modern multi-story shops with 70 to 80 per cent. of their walls composed of glass, should have 1 sq. ft. of radiation for every 130 to 150 cu. ft. of volume. In Northern latitudes with minimum temperatures of 10 to 20 degrees below zero, 1 sq. ft. of radiation may be needed for every 75 to 100 cu. ft. The amount provided in buildings of the old style, with less window area, where 1 ft. of radiation was enough for 200 to 220 cu. ft. of building, is quite insufficient in shops of the modern type.

Another approximate rule for determining the required number of lineal feet of 1-in. piping, for heating by live or exhaust steam, when air is taken from without, is to divide the cubic contents of the building by 150, and the resulting number is the number of lineal feet required. Again, dividing the number of lineal feet of 1-in. piping just found, by 70 gives the approximate required horse-power of the boiler.

In one-story metal working shops with galleries and central

traveling crane, where heating pipes cannot cross the central open space occupied by the cranes when moving, ducts must either be placed under the floors with risers at the walls, or there must be a double line of metal ducts at each side, worked by two separate blowers. In multi-story buildings, the blowers and fans are usually placed in the basement, with one or more risers or stand pipes rising to the upper floors, from which pipes branch out as in one-story shops. In new buildings these flues can be in the outer walls, this arrangment being quite suitable for such shops as textile mills.

The cost of steam heat installation is usually $3 to $4 per 1000 cu. ft., of building, or 60 to 80 cents per square foot of radiation surface.

Heating by Floor Radiation.—A system of heating by radiation from the floors which are artificially warmed, was introduced a few years ago in a shop for the Morse Chain Company at Ithaca, N. Y. In this case, hot air was admitted directly to the building only in extremely cold weather, but at all other times the shop was warmed wholly by heat radiation from the floor. Steam pipes 1-in. in diameter were laid crosswise of the building inside of 4-in. pipes buried in the concrete floors, the larger pipe being covered with ½ in. of wearing surface. A large metal working shop in Cleveland, plans for which were made partly by the writer, is heated in a somewhat similar manner. The building is 400 ft. long, and 245 ft. wide, and heaters are placed in four pits below the floor at one side of the shop. Hot air is conveyed through four main transverse concrete ducts below the floor, to openings or registers 22 in. in diameter, in the base of the columns. By using four separate heaters, the probability of a general breakdown is small, for if one should be out of repair, there would still be three in operation. Branches from the main ducts are 24-in. tile sewer pipes. The floor of the shop is concrete and granolithic—a type which is often objectionable on account of its transmitting heat rapidly from the body and causing fatigue—but in this case with heat ducts below the floor to warm it, this objection is removed.

TABLE XXI.—WEIGHT PER LINEAL FOOT OF GALVANIZED PIPES, U. S. STANDARD GAUGE

Weights in Pounds Avoirdupois per Running Foot

Diameter of pipe	Square feet per running foot	Number of gauge					
		26	24	22	20	18	16
4	1.13	1.13	1.47	1.69	1.97	2.56	3.10
5	1.39	1.39	1.80	2.08	2.43	3.19	3.82
6	1.65	1.65	2.14	2.47	2.89	3.79	4.54
7	1.91	1.91	2.48	2.86	3.34	4.39	5.25
8	2.18	2.18	2.83	3.27	3.81	5.01	6.00
9	2.44	2.44	3.17	3.66	4.27	5.61	6.71
10	2.70	2.70	3.51	4.05	4.72	6.21	7.42
11	2.96	2.96	3.85	4.44	5.18	6.80	8.14
12	3.22	3.22	4.18	4.83	5.63	7.40	8.85
13	3.48	3.48	4.52	5.22	6.09	8.00	9.57
14	3.74	3.74	4.86	5.61	6.54	8.60	10.28
15	4.01	4.01	5.21	6.01	7.01	9.22	10.86
16	4.27	4.27	5.55	6.40	7.47	9.82	11.74
17	4.53	4.53	5.85	6.79	7.92	10.42	12.45
18	4.87	4.87	6.33	7.30	8.51	11.18	13.36
19	5.14	5.14	6.68	7.71	9.00	11.80	14.11
20	5.40	5.40	7.02	8.10	9.45	12.42	14.85
21	5.59	5.59	7.26	8.39	9.78	12.85	15.36
22	5.92	5.92	7.70	8.88	10.35	13.60	16.25
23	6.18	6.18	8.04	9.27	10.81	14.40	17.00
24	6.45	6.45	8.38	9.67	11.30	14.84	17.71
25	6.71	6.71	8.72	10.06	11.74	15.41	18.41
26	6.97	6.97	9.05	10.45	12.20	16.00	19.15
27	7.33	7.33	9.40	10.85	12.67	16.62	19.87
28	7.50	7.50	9.75	11.27	13.13	17.26	20.60
29	7.75	7.75	10.07	11.63	13.58	17.81	21.30
30	8.10	8.10	10.54	12.17	14.20	18.62	22.25
31	8.36	8.36	10.87	12.54	14.63	19.20	23.00
32	8.62	8.62	11.20	12.93	15.10	19.84	23.70
33	8.88	8.88	11.56	13.34	15.56	20.42	24.40
34	9.15	9.15	11.90	13.73	16.00	21.08	25.18
35	9.41	9.41	12.23	14.10	16.48	21.65	25.85
36	9.67	9.67	12.57	14.50	16.91	22.22	26.60
37	9.93	9.93	12.91	14.90	17.40	22.84	27.30
38	10.19	10.19	13.25	15.29	17.81	23.40	28.00
39	10.46	10.46	13.60	15.60	18.31	24.02	28.70
40	10.72	10.72	13.95	16.08	18.76	24.68	29.50

TABLE XXI.—WEIGHT PER LINEAL FOOT OF GALVANIZED PIPES, U. S. STANDARD GAUGE—*Continued.*

Weights in Pounds Avoirdupois per Running Foot

Diameter of pipe	Square feet per running foot	Number of gauge					
		26	24	22	20	18	16
41	10.98	10.98	14.27	16.47	19.20	25.25	30.20
42	11.24	11.24	14.60	16.86	19.61	25.86	30.90
43	11.59	11.59	15.06	17.38	20.30	26.60	31.80
44	11.85	11.85	15.40	17.78	20.74	27.25	32.60
45	12.11	12.11	15.75	18.17	21.20	27.90	33.30
46	12.37	12.37	16.10	18.55	21.62	28.43	34.00
47	12.63	12.63	16.40	18.95	22.10	29.00	34.70
48	12.90	12.90	16.78	19.35	22.60	29.70	35.50
49	13.15	13.15	17.10	19.72	23.00	30.25	36.20
50	13.41	13.41	17.45	20.12	23.50	30.90	36.90
51	13.66	13.66	17.75	20.49	23.90	31.40	37.50
52	13.94	13.94	18.12	20.97	24.40	32.00	38.30
53	14.20	14.20	18.46	21.30	24.90	32.66	39.00
54	14.46	14.46	18.80	21.69	25.30	33.20	39.70
55	14.81	14.81	19.28	22.22	25.94	34.10	40.80
56	15.07	15.07	19.60	22.61	26.40	34.65	41.40
57	15.33	15.33	19.95	23.00	26.80	35.21	42.10
58	15.58	15.58	20.30	23.37	27.30	35.84	42.80
59	15.83	15.83	20.55	23.74	27.70	36.40	43.50
60	16.12	16.12	20.95	24.18	28.20	37.00	44.30
62	16.65	16.65	21.65	24.97	29.10	38.20	45.70
64	17.16	17.16	22.30	25.74	30.00	39.50	47.20
66	17.66	17.66	22.97	26.49	30.90	40.60	48.50
68	18.21	18.21	23.65	27.31	31.83	41.80	50.00
70	18.75	18.75	24.40	28.12	32.80	43.10	51.50
72	19.25	19.25	25.02	29.92	33.70	44.30	53.00
74	19.79	19.79	25.70	29.68	34.65	45.50	54.50
76					35.62	45.77	54.73
78					35.75	46.96	55.13
80					36.65	48.16	56.63
82					37.57	49.40	58.00
84					38.50	50.60	59.40
86					39.39	51.77	60.77

Heating and ventilating	For planing-mill work
Ducts to 18 in. diameter, 26 gal.	Ducts to 8 in. diameter, 24 gal.
Ducts 19 to 29 in. diameter, 24 gal.	Ducts 9 to 14 in. diameter, 22 gal.
Ducts 30 to 39 in. diameter, 22 gal.	Ducts 15 to 20 in. diameter, 20 gal.
Ducts 40 to 49 in. diameter, 20 gal.	Ducts 21 to 30 in. diameter, 18 gal.
Ducts 50 to 70 in. diameter, 18 gal.	
Above 70 in. diameter, 16 gal.	

TABLE. XXII—CARRYING CAPACITY OF PIPES

Cubic feet of air per minute	Velocities											
	500	600	800	1000	1200	1500	1800	2000	2500	3000	3500	4000
200	9	8	7	7	6	6	6	6	6	6	6	6
400	13	11	10	9	8	8	7	7	6	6	6	6
600	15	14	12	11	10	9	8	8	7	7	6	6
800	18	16	14	13	12	10	9	9	8	8	7	7
1,000	20	18	16	14	13	12	10	10	9	8	8	7
1,200	21	20	17	15	14	13	11	11	10	9	9	8
1,400	23	21	18	16	15	14	12	12	11	10	9	9
1,600	25	23	20	18	16	15	13	13	11	11	10	9
1,800	26	24	21	19	17	15	14	13	12	11	10	10
2,000	28	25	22	20	18	16	15	14	13	12	11	10
2,200	29	27	23	21	19	17	15	15	13	12	11	11
2,400	30	28	24	21	20	18	16	15	14	13	12	11
2,600	31	29	25	22	20	18	17	16	15	13	12	11
2,800	33	30	26	23	21	19	18	16	15	14	13	12
3,000	34	31	27	24	22	20	18	17	15	14	13	12
3,200	34	32	28	25	23	20	19	18	15	15	13	13
3,400	36	33	28	25	23	21	19	18	16	15	14	13
3,600	37	34	29	26	24	21	20	19	16	15	14	13
3,800	38	35	30	27	25	22	21	19	17	16	15	14
4,000	39	35	31	28	25	22	21	20	18	16	15	14
4,200	40	36	32	28	26	23	21	20	18	16	15	14
4,400	41	37	32	29	26	24	22	21	18	17	16	15
4,600	42	38	33	30	27	24	22	21	19	17	16	15
4,800	42	39	34	30	28	25	22	21	19	18	16	15
5,000	43	40	34	31	28	25	23	22	20	18	17	16
5,200	44	40	35	31	29	25	24	22	20	18	17	16
5,400	....	....	35	32	29	26	24	23	21	18	18	16
5,600	....	....	36	33	30	27	24	23	21	19	18	17
5,800	....	....	37	33	30	27	25	24	21	19	18	17
6,000	....	....	38	34	31	28	25	24	21	20	18	17
6,200	....	....	38	34	31	28	25	24	21	20	18	17
6,400	....	....	39	35	32	28	26	25	22	20	19	18
6,600	....	....	39	36	32	29	26	25	22	21	19	18
6,800	....	....	40	36	33	29	27	25	23	21	19	18
7,000	....	....	40	36	33	30	27	26	23	21	19	18
7,200	....	....	41	37	34	30	28	26	23	21	20	19
7,400	....	....	41	37	34	30	28	27	24	21	20	19
7,600	....	....	42	38	34	31	28	27	24	22	20	19

TABLE XXII.—CARRYING CAPACITY OF PIPES—*Continued*

Cubic feet of air per minute	Velocities										
			800	1000	1200	1500	1800	2000	2500	3000	3500	4000
7,800	....	....	43	38	36	31	29	27	24	22	21	19
8,000	....	....	43	39	36	32	29	28	25	22	21	20
8,200	....	....	....	39	36	32	29	28	25	23	21	20
8,400	....	....	....	40	36	33	30	28	25	23	21	20
8,600	....	....	....	40	37	33	30	29	25	23	21	20
8,800	....	....	....	41	37	33	30	29	26	24	22	21
9,000	....	....	....	41	38	34	31	29	26	24	22	21
9,200	....	....	....	41	38	34	31	30	26	24	22	21
9,400	....	....	....	42	38	34	31	30	27	24	22	21
9,600	....	....	....	42	39	35	32	30	27	25	23	21
9,800	....	....	....	43	39	36	32	30	27	25	23	21
10,000	....	....	....	43	40	36	32	31	28	25	23	22
11,000	....	....	....	45	41	37	33	31	29	26	24	23
12,000	....	....	....	47	43	39	35	34	30	28	25	24
13,000	....	....	....	49	45	40	37	35	31	29	27	25
14,000	....	....	....	51	47	42	38	36	33	30	28	26
15,000	....	....	....	53	48	43	40	38	34	31	28	27
16,000	....	....	....	55	50	45	41	39	35	32	29	28
17,000	....	....	....	56	51	46	42	40	36	33	30	28
18,000	....	....	....	58	53	47	43	41	37	34	31	29
19,000	....	....	....	60	54	49	44	42	38	34	32	30
20,000	....	....	....	61	56	50	46	43	39	35	33	31
21,000	....	....	....	63	57	51	47	44	40	36	34	31
22,000	....	....	....	64	58	52	48	45	41	37	34	32
23,000	....	....	....	65	60	53	49	46	42	38	35	33
24,000	....	....	....	67	61	55	50	47	42	39	36	34
25,000	....	....	....	68	62	56	51	48	43	40	37	34
26,000	....	....	....	70	63	57	52	49	44	40	38	35
27,000	....	....	....	71	65	58	53	50	45	41	38	36
28,000	....	....	....	72	66	59	54	51	46	42	39	36
29,000	....	....	....	73	67	60	55	52	47	42	39	37
30,000	....	....	....	75	68	61	56	53	47	43	40	38
31,000	....	....	....	76	69	62	57	54	48	44	41	38
32,000	....	....	....	77	70	63	57	55	49	45	41	39
33,000	....	....	....	78	72	64	58	56	50	45	42	39
34,000	....	....	....	79	73	65	59	56	50	46	43	40
35,000	....	....	....	81	74	66	60	57	51	47	43	40
36,000	....	....	....	82	75	67	61	58	52	47	44	41

TABLE XXII.—CARRYING CAPACITY OF PIPES—*Continued*

Cubic feet of air per minute	Velocities											
				1000	1200	1500	1800	2200	2500	3000	3500	4000
37,000	....	....	....	83	76	68	62	59	52	48	44	42
38,000	....	....	....	84	77	69	63	60	53	49	45	42
39,000	....	....	....	85	78	70	63	60	54	49	46	43
40,000	....	....	....	86	79	71	64	61	55	50	46	43
41,000	....	....	....	87	79	71	65	62	55	50	47	44
42,000	....	....	....	88	81	72	66	63	56	51	47	44
43,000	....	....	....	89	82	73	66	63	57	51	48	44
44,000	....	....	....	90	82	74	67	64	57	52	48	45
45,000	....	....	....	91	83	75	68	65	58	53	49	46
46,000	....	....	....	93	84	75	69	65	59	53	50	46
47,000	....	....	....	93	85	76	70	66	59	54	50	47
48,000	....	....	....	95	86	77	70	67	60	55	50	47
49,000	....	....	....	95	87	78	71	68	60	55	51	48
50,000	....	....	....	96	88	79	72	68	61	56	51	48
51,000	....	....	....	97	89	79	73	69	62	56	52	49
52,000	....	....	....	98	90	80	73	70	62	57	53	49
53,000	....	....	....	99	90	71	74	70	63	57	53	50
54,000	....	....	....	....	91	82	75	68	63	58	54	50
55,000	....	....	....	....	92	82	75	68	64	58	54	51
56,000	....	....	....	....	93	83	76	69	65	59	55	51
57,000	....	....	....	....	94	84	77	69	65	60	55	52
58,000	....	....	....	....	95	85	77	70	66	60	56	52
59,000	....	....	....	....	95	85	78	71	66	60	56	52
60,000	....	....	....	....	96	86	79	71	67	61	57	53
61,000	....	....	....	....	97	87	79	72	67	62	57	53
62,000	....	....	....	....	98	88	80	72	68	62	57	54
63,000	....	....	....	....	....	....	....	73	68	63	58	54
64,000	....	....	....	....	....	....	....	73	69	63	58	55
65,000	....	....	....	....	....	....	....	74	70	63	59	55
66,000	....	....	....	....	....	....	....	75	70	64	59	56
67,000	....	....	....	....	....	....	....	75	71	64	60	56
68,000	....	....	....	....	....	....	....	76	71	65	60	56
69,000	....	....	....	....	....	....	....	76	71	66	61	57
70,000	....	....	....	....	....	....	....	77	72	66	61	57
71,000	....	....	....	....	....	....	....	77	73	66	61	57
72,000	....	....	....	....	....	....	....	78	73	67	62	58
73,000	....	....	....	....	....	....	....	78	74	67	62	58
74,000	....	....	....	....	....	....	....	79	74	68	63	59

TABLE XXII.—CARRYING CAPACITY OF PIPES—*Continued*

Cubic feet of air per minute	Velocities										
								2200	2500	3000	3500	4000
75,000	....	....	....	....	....	....	....	79	75	68	63	59
76,000	....	....	....	....	....	....	....	80	75	69	64	60
77,000	....	....	....	....	....	....	....	81	76	69	64	60
78,000	....	....	....	....	....	....	....	81	76	70	64	60
79,000	....	....	....	....	....	....	....	82	77	70	65	61
80,000	....	....	....	....	....	....	....	82	77	70	65	61
81,000	....	....	....	....	....	....	....	83	78	71	66	61
82,000	....	....	....	....	....	....	....	83	78	71	66	62
83,000	....	....	....	....	....	....	....	84	79	72	66	62
84,000	....	....	....	....	....	....	....	84	79	72	67	63
85,000	....	....	....	....	....	....	....	85	79	73	67	63
86,000	....	....	....	....	....	....	....	85	80	73	68	63
87,000	....	....	....	....	....	....	....	86	80	73	68	64
88,000	....	....	....	....	....	....	....	86	81	74	68	64
89,000	....	....	....	....	....	....	....	87	81	74	69	64
90,000	....	....	....	....	....	....	....	87	82	75	69	65
91,000	....	....	....	....	....	....	....	88	82	75	70	65
92,000	....	....	....	....	....	....	....	88	83	75	70	65
93,000	....	....	....	....	....	....	....	88	83	76	70	66
94,000	....	....	....	....	....	....	....	89	84	76	71	66
95,000	....	....	....	....	....	....	....	89	84	77	71	66
96,000	....	....	....	....	....	....	....	90	84	77	71	67
97,000	....	....	....	....	....	....	....	90	85	77	72	67
98,000	....	....	....	....	....	....	....	91	85	78	72	68
99,000	....	....	....	....	....	....	....	91	86	78	72	68
100,000	....	....	....	....	....	....	....	92	86	79	73	68

CHAPTER XXI

AIR WASHING SYSTEMS

Several effective systems are available for washing and purifying air before forcing it by fans to different parts of buildings. These include the Carrier, Webster, Acme, Kinealy, and others. All are much alike in essential principles, though they differ somewhat in detail.

The chief features of air washing and humidifying systems are the spray, separator, and the method of humidity control. The first of these is one of the most important elements. It is essential that the water be divided as finely and distributed as

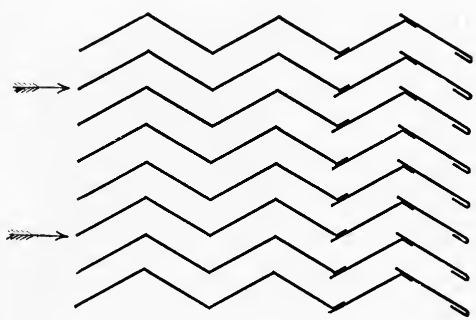


Fig. 128.—Eliminator plates.

evenly as possible, and one way of obtaining these results is by a special type and arrangement of nozzles. The centrifugal force generated by the rapid rotation of water in a nozzle causes the stream to burst into an invisible mist upon leaving the orifice. The distribution of the spray from simple brass nozzles is even and practically uniform over the entire area of discharge. When dependence is placed on lateral discharge, the necessarily high velocity of the air through the chamber so disturbs the normal form of the spray that an even distribution is impossible. The sprays may, however, be distributed in great numbers over the entire area of the chamber and the direction of the discharge

made nearly parallel to the air current. In this way, there will be no undesirable distortion of the discharge and the chamber will be uniformly and completely filled with a perfectly atomized spray. Pipe fittings should be either galvanized or of brass, to

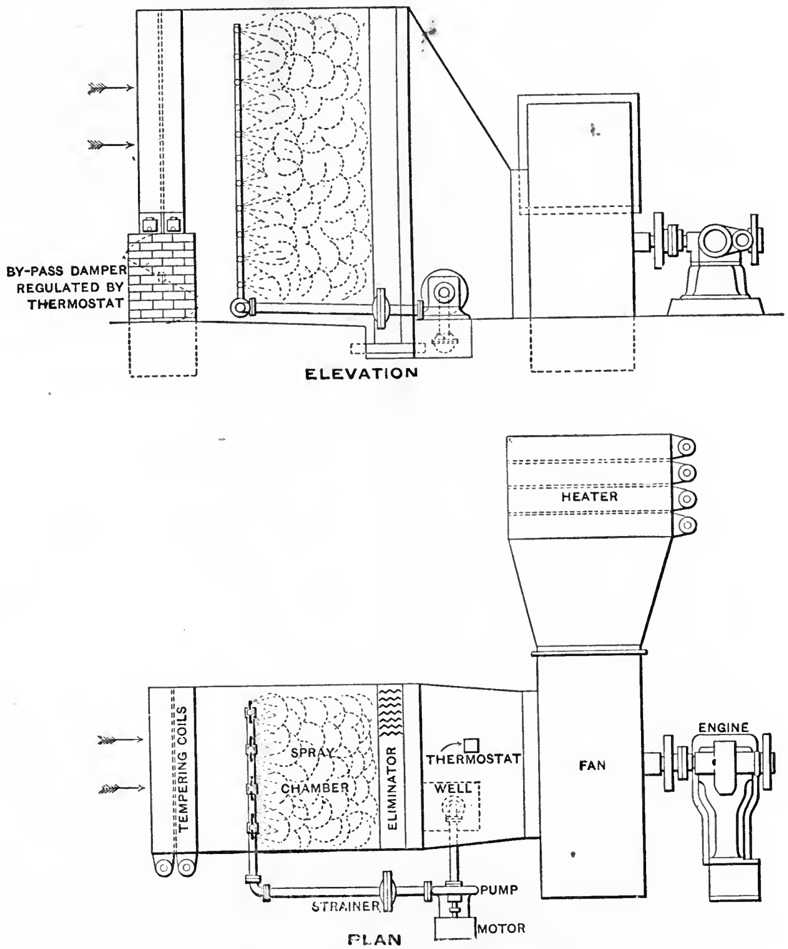


Fig. 129.—Air purifier and humidifier.

prevent corrosion, and a suitable strainer should be provided. The design of the nozzles and of the systems should be such that no stoppage or choking can occur.

Construction of Eliminator.—After the spray water has per-

formed its function of cleaning, moistening and cooling the air, all free particles of moisture and impurities should be removed; at the same time, no excessive resistance must be offered to the air passage which will interfere with the ventilation. This can be accomplished by an arrangement of baffle plates, placed nearly vertical and parallel to each other, with a space between, forming a series of unbroken sinuous passageways. Each baffle is composed of a number of bent plates fastened together. The plates should be non-corroding and may be constructed of sheet copper at some additional cost. Owing to their form, the plates are rigid without excessive weight, and they should be fastened together in a substantial manner. The eliminator should be self-contained and have a flange connection for attachment to the spray chamber and to the fan casing. It should be rigidly braced by angle irons and supported on a galvanized structural iron foundation.

Action of Eliminator.—The first portion of the eliminator is covered with a sheet of running water precipitated from the spray laden air. The air passing through this portion impinges upon the wet surface and all solid particles in the air are caught and washed away. The second portion contains lip-like projections which prevent the free passage of water across the surface and form vertical gutters down which the water flows. No trace of free moisture will be found in the air after passing through the eliminator, even with high velocities. The loss in pressure of the air in passing through the separator is inappreciable when standard proportions are used.

Spray Chamber.—The spray chamber should be made of heavy galvanized iron throughout and stiffly braced on the outside with $1\frac{1}{2}$-in. angle irons. It should be put together in flanged sections and be watertight.

Pumps.—The spray system may be operated from the city pressure, although it is usual to pump the water over and over again until it becomes unfit for use. The latter plan requires a pump, a receiving tank with settling chamber, a strainer, an automatic supply and an overflow. A centrifugal pump is convenient for it can be made nearly noiseless in operation, and may be belted directly from the fan shaft or driven by a small direct-connected motor. There are no valves to wear out or become clogged, making it superior to a piston pump for continuous service.

Hygrodeik.—The common forms of hydrometers make it necessary for the observer after reading the wet and dry bulb temperatures, to refer to a chart and calculate the relative

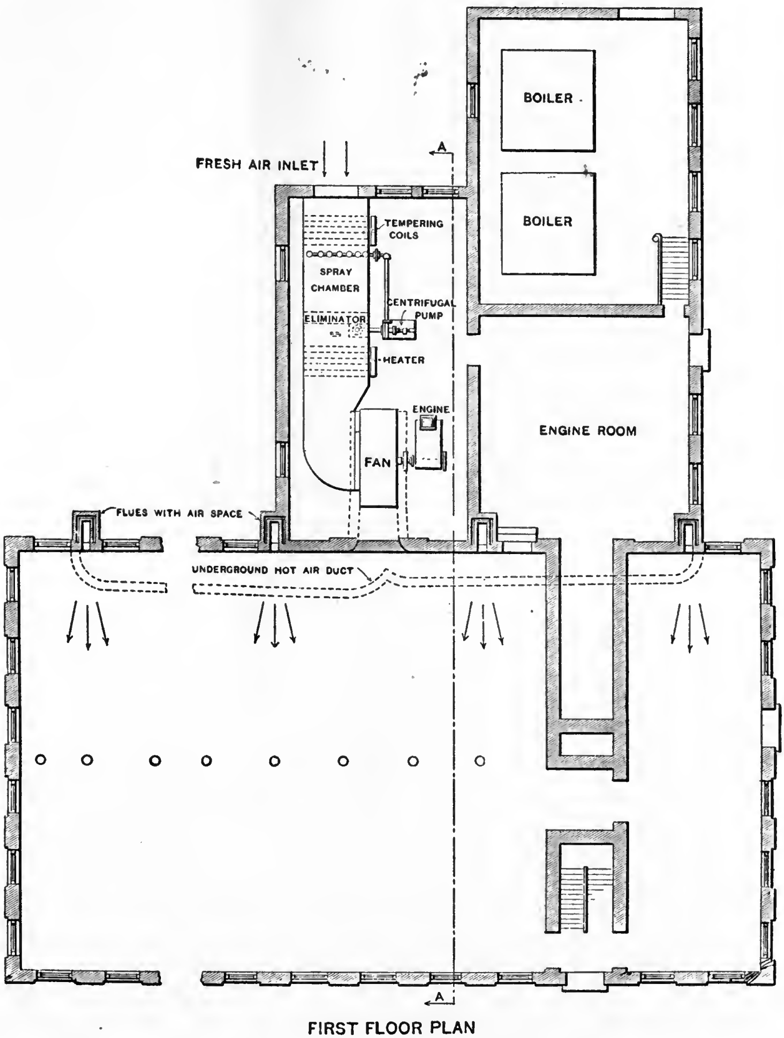


Fig. 130.—Fan system in a cotton mill.

humidity. Instruments which indicate the relative humidity direct are unreliable; the hygrodeik consists of wet and dry bulb thermometers mounted in such a position that with the

assistance of the diagram and pointer, the reading is taken with ease and accuracy. They are made in various styles, ranging in price from $7 to $11.

Gas Heater.—The adaptation of the gas heater to provide for warming the air entering a heating and ventilating system represents a field for use quite distinct from those employing steam heated radiating coils. Its use is applicable to any situation where economy and particularly cleanliness, minimum amount of apparatus, and automatic operation are desirable features. Reports of tests read before the American Society of Mechanical Engineers in 1905, show efficiency of gas-fired steam boilers to be seldom in excess of 65 to 75°, yet this can be exceeded in the guaranteed efficiency of the heater used, which may have a special arrangement for the return of a portion of the flue gases. Besides, the direct-heat furnace is much cheaper to install than a gas-fired boiler and steam coil, hence, its wide application in natural gas belts or where fuel gas can be obtained at ordinary cost. In the case of a roundhouse at Parsons, Kansas, the design insures an efficiency of 90 per cent. at full capacity with maximum furnace temperature not exceeding 1200°, and a minimum temperature of waste gases about 400°.

General Arrangement.—The apparatus consists in general of a bank of vertical boiler tubes expanded at top and bottom into wrought-iron boiler plates. The space between the tubes can be placed below the floor line, and divided into two compartments. The first compartment comprises the furnace proper, where the gas is burned under general conditions described later. The other portion underneath the tubes is simply an exhaust chamber for the waste gases. Above the tubes is located a single chamber which has a removable sectional cover to provide for cleaning and inspection of tubes. The path of the gases is thus upward through the tubes from the lower to the upper chamber, and hence downward through the tubes to the chamber underneath. Above the tubes is an exhaust fan which handles waste gases. The bank of tubes is enclosed at top, bottom and two sides, and the current of air for heating purposes is drawn through by a motor-driven steel plate exhauster. From this fan the air heated to a temperature of about 170° is distributed through galvanized iron ducts in the usual manner.

Operation.—The general process consists in first burning the gas in a fire-brick combustion chamber at high temperature and with

very small excess of air, and, second, mixing this small volume of hot gases at high temperature with a larger volume of the recirculated products of combustion at the relatively low temperature of about 400°, giving a resulting temperature not exceeding 1200°.

Where natural gas is not available, a gas furnace heating system may be operated quite as economically as a steam heating system. The average gas producer in the market, using

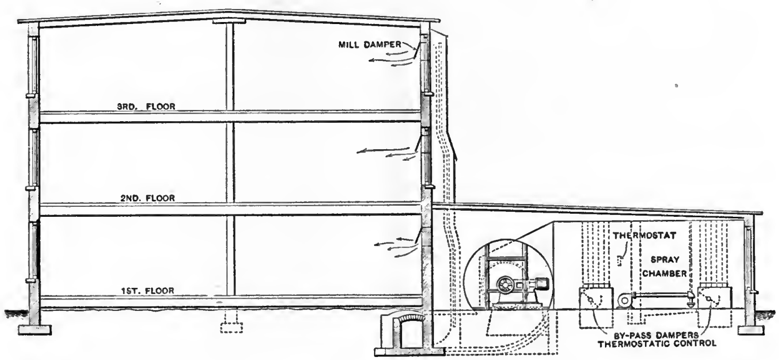


FIG. 131.—Fan system applied to a cotton mill.

soft coal, will give an efficiency of about 65 to 70 per cent. This would give a combined efficiency of gas producer and gas heater of about 59 to 63 per cent. In such a system it is customary to provide for the utilization of the exhaust from the gas engines which may be introduced into the lowest chamber. This exhaust alone is frequently sufficient to heat the entire building in moderate weather.

CHAPTER XXII.

FACTORY LIGHTING

With the comparatively recent introduction not only of new, but of medium sized light units, the art of illumination may be said to have developed into the science of illuminating engineering. This change, with the far-reaching possibilities involved in it, is as yet but imperfectly understood by the public at large, and time, therefore, will be required to demonstrate the tremendous advantages to be derived from a scientific analysis now attainable, of any lighting problem as against the cut-and-try method of arriving at a solution heretofore in common use.

Illuminating engineering when applied to any special case, seeks to determine the light best adapted for the purpose, having due regard for all conditions, and embraces such factors as quantity, quality, distribution, continuity of service, surroundings, costs, etc. The large variety of light units and the accessory apparatus now available, render a determination of the proper kind of unit no longer a perplexity but a comparatively simple matter. One of the hardest things the illuminating engineer has to contend with, however, especially in interior lighting, is the difficulty in setting down in figures the total economy—not merely in the production of light itself but also that made possible by its use—which may be affected by a modern system of lighting, and this is particularly true in plants already equipped with lighting facilities, inadequate though these may be in many cases.

Among the several items contributing to the total gain are the following:

1. Decrease in cost of operation and maintenance of the lighting system, or increase in the quantity and quality of the lighting for the same cost.
2. Greater accuracy in workmanship with consequent lessening of defective work.
3. Increase in production with accompanying decrease in cost.
4. Reduced liability to accidents.

5. Lessening of eye strain.
6. More cheerful surroundings.

It will be seen from this list that while the first of these items will readily be appreciated by everybody, since it can be measured in exact money values, such is not the case with the others; in fact the very existence of some of them may perhaps be a novel thought to many people who have not given the subject of lighting any particular study.

Ten years ago factory electric lighting was limited to the carbon filament and arc lamp. The smaller unit, the incandescent lamp, is still very useful where the special placing of small lamps is necessary. Likewise the arc lamp is useful for large and high areas such as high bays of large machine shops, foundries and the like. But neither of these serves for those intermediate conditions typified by large rooms with ceilings from 12 to 18 ft. in height. The small lamps did not give enough light unless used in large numbers, clusters often being employed which were in general expensive and unsatisfactory. The arc lamps in such cases required considerable separation and provided poor distribution, not a very satisfactory illumination, and usually an intense light in the line of vision.

Within the last few years, tungsten lamps of various sizes have been introduced, with candle-power values lying between and overlapping those of the enclosed arc and the carbon filament lamps. The relative efficiences of the old types and the new tungsten lamps may be roughly stated to be 2 to 1 with the old enclosed arc lamps, and from 3 to 1, to 4 to 1, with the carbon filament lamps. The introduction of these lamps has made possible what may be termed a new era in factory illumination, a distinctive feature of which is the scientific installation of the light units, suiting each to the location and class of work for which it is best adapted. This was formerly impossible with either the arc or carbon filament lamps.

The Candle-power of Units.—Before the introduction in recent years of medium sized units, the choice of the size of unit for a given location was often no choice at all. In many cases, due to small clearance between cranes and ceilings, or other conditions making it necessary to mount the lamps very high above the floor, but one size or type of unit was available, the carbon filament lamp in the former and the enclosed carbon arc lamp in the latter case.

For low ceilings up to 18 ft., the use either of the carbon filament or arc lamp resulted usually in anything but uniform illumination over the working plane, and often produced merely a low general illumination which was practically useless for the individual machines. In such cases, individual lamps had to be placed over the machines. With this arrangement, relatively small areas are lighted, and the metal shades usually employed only serve to accentuate the "spot-lighting" effect. Such a form of illumination for factory work is unsatisfactory and inefficient, but as stated, was in many cases the only available scheme. The absence of lamps of the proper size is no longer an excuse for the existence of such conditions in industrial plants.

Relation of Lighting Problems to Efficient Management.—In factory work, efficiency should be considered from at least two view-points, in the one case, that of the machine, and in the other, that of the workman. The surrounding conditions under which work is done are of prime importance when considering the items which contribute to man-efficiency. Among these conditions is that of artificial light. Poor illumination produces a bodily and mental discomfort which seriously affects the man and his work. When the work is seen with difficulty, when the drawings are indistinct and the surroundings dim and gloomy, the conditions necessary for high efficiency are lacking. In those instances, therefore, where superior illumination improves the physical characteristics which tend toward a better class of work and affords more cheerful conditions, it should, without question, be provided.

How much is the accuracy and general quality of workmanship improved by good instead of poor lighting results?

How much does the stimulating effect of bright surroundings contribute to cheerfulness of mind and alertness of action?

How many mistakes in reading figures on blueprints or on scales are due to poor illumination?

How much fatigue and eye strain and impaired vision is caused by inferior or improper lighting?

To what extent are accidents to machinery and to workmen decreased by having good instead of poor illumination?

It is difficult to answer these questions in a definite manner, but no one familiar with industrial conditions will take exception to the statement that good illumination, of a sufficiently high intensity, is better than that of a low and insufficient inten-

sity. And if it can be shown that the actual cost of good illumination is small compared with the value of the advantages secured, then inadequate lighting has no defence.

The practical problems involved in planning a lighting system are the determination of the factors which constitute good illumination, by careful study of the exact conditions under which the light is to be used, and the adaptation of the means at hand to these conditions. Simple as these problems may seem, when carefully analyzed, they will be found to be much more intricate and involved than might be expected.

Importance of Good Illumination in Factory Work.—Adequate illumination increases output. A saving of even several minutes per day for the workmen will soon pay for the entire cost of installing and operating a suitable factory lighting system. The lighting of industrial plants is one of the factors which promotes efficiency. Like good ventilation, and adequate heating system, or cleanliness and neatness, a good lighting system is a necessary item in maintaining a high standard of workmanship. In the early morning and late afternoon hours, and on cloudy days, many factories are in practical darkness as far as daylight is concerned. No one single factor is as important as light, whether natural or artificial, as an aid in keeping production at a high efficiency throughout the entire working day. As the night turn is entirely dependent on artificial light, the importance of factory lighting from this standpoint cannot be overestimated.

The Relative Cost Factors of Light.—The manager is perhaps most concerned with the cash value of the light. How much of a return in quantity and quality of work will result from the adoption of a superior system as compared with an inferior one, is the determining question. The value of good light may be placed in terms of time saved by the employee in performing a given amount of work, in the greater accuracy and perfection of the work, in the saving of the eyes of the workmen, and in promoting the fa ilities for better and more work by providing brighter and more cheerful surroundings. If then, better light may be interpreted in terms of so much time saved by the employee in factory operation, the equivalent in wages of this time saved, is an asset of the improved lighting system.

Assume that the annual operation and maintenance cost for a typical factory bay, 16 ft. by 40 ft., may be taken as $50. Assume further that such a bay will accommodate five workmen

whose hourly rate averages 25 cents and whose annual wages equal $3500. By adding to this labor cost 100 per cent. for overhead burden or indirect factory expense, the gross annual cost of the bay will total $7000. Since the cost of operation and maintenance of the lighting is $50, it is, therefore, only 0.7 per cent. of $7000, or 0.7 per cent. of the gross wages. This per cent. of the wages for a day of ten hours is equivalent in time to a little over four minutes. It is not unreasonable to assume that poor lighting will cost at least one-half of this, or two minutes in wages. Surely, therefore, if good light enables a workman to do better or more work to an extent equal to only two minutes in wages per day, the additional cost of good lighting over inadequate lighting will certainly have paid for itself.

In one case a superintendent said that his men lost from one to two hours per day on dark days, due to insufficient light. This meant that the wages paid for an hour or two each day was a complete loss to the company. Often, therefore, an apparently expensive lighting equipment will prove economical. If one kind of light has a marked advantage over another, its use will result in better or more work, fewer delays, less eye strain, and in general, greater satisfaction.

General Requirements.—No factory can afford to have its employees working under an inadequate illumination, as the losses in output far overbalance any supposed economy in the energy which may be saved by such means.

Factory lighting should be reliable—unsteady or inreliable light is very demoralizing.

Specially, factory lighting should provide the following features:

1. Adequate light for each employee.
2. Good illumination everywhere on the working plane, and, if possible, when the floor space is crowded with workmen the illumination should be of a satisfactory intensity without regard to the location of the work; that is, the illumination should be uniform throughout the entire shop.
3. Such illumination as to make individual carbon filament lamps unnecessary except in very special cases. Sometimes, however, individual lamps on machines must be provided.
4. Illumination provided by an arrangement and size of units which avoids glare due to light from an intense source striking the eye.

The preceding requirements should be fulfilled by a type of lamp suitable to the class of work performed, and to general physical conditions, such as clearance between cranes and ceilings.

Certain Items Bearing on Effective Illumination.—The intensity of illumination on the working surface is one of the important items which determine the success or failure of any lighting system. The eye is affected by the intensity of the light reflected from the object, rather than by the intensity of the light on the object. Hence where the materials or parts are of a very dark color, more light may be required for a certain factory space than where the work is lighter in color. For this reason factory conditions often present difficulties in the matter of proper illumination which are not in evidence in office work, or in installations of a different class. The required intensity of the illumination for various kinds of work is an item impossible to completely specify. It has been found that 2.5 foot-candles on the working surface is sufficient for machine work where practically no daylight is present. In other cases where light is required on the sides of objects, and where the work itself is of a nature requiring the distinction of much detail, illumination intensities of five foot-candles and over are sometimes necessary.

The intensity of the illumination is not, however, always the most important feature. In some cases where color contrast is largely lacking, an increase in the intensity will not better conditions. In other cases, the discrimination is based almost entirely on shadow effect. In finishing a die for a punching, dependence may be placed almost entirely on the shadows along the edges of the die in judging of the exactness of the fit. In an instance of this kind, a drop lamp in the hands of the workman, who can thus control the direction of the light, will be far better than any amount of overhead illumination, no matter what the intensity.

Classification of Problems in Factory Work.—A classification, in complete form, of the various cases included under this head will be hardly possible of successful accomplishment. Factory lighting problems might be grouped according to surroundings, that is, whether ceiling and walls are light or dark; the presence or absence of line shafting and belting; the work, whether flat, as in the case of some bench work, or consisting of high machines and other obstructions to light. It might also be grouped according to the height of ceiling and width of location, although

in such a scheme, two spaces of the same dimensions and ceiling height might call for entirely separate illumination plans due to other conditions, as before suggested. For these reasons a complete classification of work of this kind is hardly possible or even advantageous. It has, however, been found convenient and helpful in a given factory to separate the lighting problems in the various locations according to ceiling heights, because the size of lamps and their spacing depend to a large extent on this factor. Low ceilings generally call for small or medium sized lamps, while large lamps are more applicable to the higher ceilings and mounting heights.

The Overhead Method of Lighting.—A system of lighting in which the lamps are mounted above the heads of the workmen can be made to fulfill most, if not all, of the requirements better than other systems. The advantages of this so-called overhead system as compared with those in which individual carbon filament lamps mainly are depended upon, are as follows:

1. Such a system can be made to furnish good illumination at each point of the working plane, thus permitting work to be done with equal comfort at any point.

2. In many cases it can be made to furnish a light of such quality as practically to eliminate the necessity for individual lamps.

3. By mounting the lamps at the proper height and making a selection of the proper size, glare can be practically eliminated.

4. The eye is subject to a harmful effect from the use of a single lamp placed directly over and close to the work. The bright spot of light, generally of too high an intensity, about the work, if surrounded by a region of comparative darkness, causes the eye to become fatigued since the line of vision is continually changing from the bright area to the darker surroundings. This strain on the eye can be largely avoided if the entire working surface is provided with a uniform illumination of moderate intensity.

5. Economy in maintenance is secured as compared with a system with large numbers of drop lamps.

6. The appearance is neater and more pleasing.

Examples.—A few instances of the satisfactory results obtained with this method of lighting will serve to show with what favor it is viewed.

In one factory location with low ceilings, carbon filament

clusters with individual incandescent lamps over each machine had been in service. A system of 100-watt tungsten lamps was installed, practically all individual lamps being removed from the lathes and other machines. The whole appearance was made more cheerful. The manager stated that the problem of men desiring to be transferred to other departments on account of the darkness, was solved. Some of the workmen were overheard to say that tools and machine parts were found which up to that time had been lost in corners due to the dark surroundings, the shop receiving practically no daylight and therefore having been constantly in partial darkness.

In another instance where tungsten lamps replaced a poor system of very large units, supplemented by individual lamps, the superintendent stated that on many days, because of insufficient light in the early morning and the late afternoon hours, his workmen lost one and one-half hours per day. This condition was entirely changed by installing the overhead system. Practically all drop lamps were removed. In still another factory location a superintendent blamed defective work to inadequate light. He stated that he had experienced great difficulty in retaining a good class of help. Large tungsten lamps transformed the dark and dingy location to one of cheerful and pleasing appearance, and put an end to complaints.

Another factory location had been in almost complete darkness as far as overhead lighting was concerned. The almost humorous statement was made upon the installation of a good overhead system, that the men did not wear out their shoes as fast as formerly—meaning that the matter of getting around had been complicated by their stumbling against the loose iron and material which had been allowed to accumulate on the floor when the illumination was so poor. An inspection of the place after the new system was installed showed it to be in perfect order and the floor space neat and clean. Much satisfaction was evidenced by the workmen.

The substitution of an overhead system will promote a higher efficiency of production, as well as greater cheerfulness and a better spirit among the workmen, which though difficult to express in money value, forms a distinct feature in the promotion of good and efficient workmanship.

Glare.—One of the most pernicious effects of improperly arranged lamps is the glare produced by a source of considerable

brilliancy when unshielded from the eye. In factory work the points which have a large bearing on the glare, may be noted under the four following divisions:

1. **Mounting Height of Lamp.**—As a general rule, it is best to mount all lamps well out of range of vision. The argument that the lamps should be close to the work for the purpose of gaining the greatest effectiveness from the lamps is poorly founded, since the increase in intensity by mounting them low may be more than offset by the evil effect on the eye produced by lamps mounted in the line of vision.

2. **Size of Lamps.**—The size of lamps has much to do with glare. It has been found that where the ceiling is low a small lamp is not nearly so trying to the eye as a large one.

3. **Spacing of Lamps.**—The spacing has a certain bearing on the glare, since the closer the lamps the smaller may be their size to provide a given intensity.

4. **Type of Reflectors Used.**—While modern reflectors have, as one of their greatest claims, the resulting increase in efficiency of light distribution, the protection afforded in shielding the eye from the lamp filament is also a very important item.

Shielding Effect of Girders.—Very often in factory constructions, glare may be much reduced by mounting the lamps so that they are protected by some feature of the building construction. Thus in the room shown in Fig. 132, the girders afford an excellent protection for the eye, while in that shown in Fig. 133, the lamps are all visible down the aisle whenever a workman looks up from his work.

Selection of Lamps.—The selection of lamp units best adapted to factory conditions and their most advantageous installation are two essential factors of shop lighting. The questions involved are: proper number and size of units; their best arrangement; economy in operation; relative first cost, and installation costs.

Number of Lamps per Unit of Floor Space.—On this item depends the realization of a uniform and satisfactory distribution of the light. Care should be taken to choose the number of units per unit of floor space, which will furnish a sufficiently uniform illumination to meet the important condition, that work can be performed at any point on the floor without regard to location. The next step will be that of selecting a size and type of unit which, with correct spacing, will furnish an illumin-

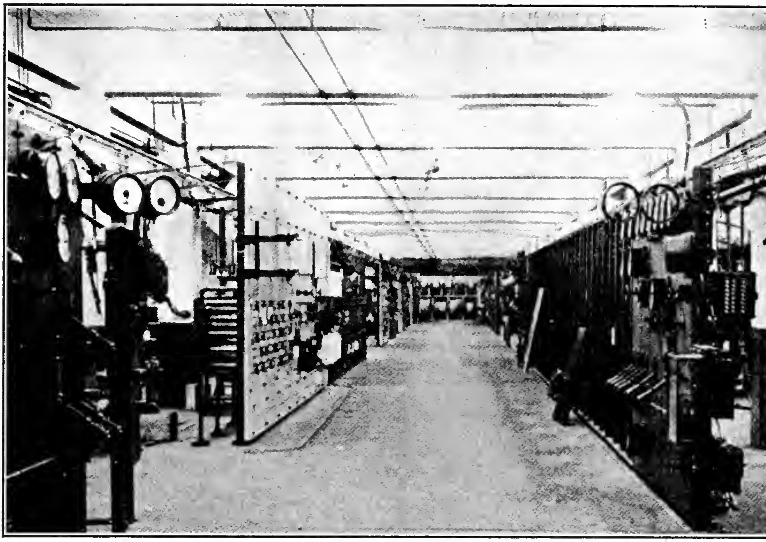


FIG. 132.—Shop interior at night. Vertical surfaces well illuminated.

FIG. 133.—Shop interior at night.

ation of sufficient intensity. An example will illustrate this point.

250-Watt versus 100-Watt Units.—A large area was to be lighted, and 250-watt tungsten lamps provided in such numbers as to give a uniform and sufficient intensity of illumination, appeared desirable. The use of this fairly large unit would have resulted in a somewhat low first cost of installation, the number of lamps per unit area being small. There were so many workmen in each bay, however, that men located at certain positions with respect to the lamps would have worked to a disadvantage because of marked shadows. It was important that work be done with ease at any point of the floor space. In this particular instance, carbon filament lamps had been used for years as drop lights over each bench. With repeated shifting of the work a continual adjustment of these drop lights was necessary. This maintenance expense was considered sufficiently large to be a factor in the substitution of an overhead lighting system and the subsequent removal of all drop lights.

Here the use of nine 100-Watt tungsten lamps, per standard 25 by 25-ft. bay, rather than four 250-watt lamps, produced a satisfactory result. It should be noted that the choice of the number of units per bay depended on the furnishing of light equally good in every direction at any point in the bay. The use of the 250-watt lamps would have resulted in a distribution as uniform, and an intensity equally great, without fulfilling the main requirement in the matter of direction, which in this case was important.

Size of Lamps.—At present the size of units is a much larger factor than ever before. If the ceiling height is low, say 12 ft. or under, the use of arc lamps is objectionable because of their relatively high candle-power; and besides the glare, the lamps cannot be used economically in sufficient numbers to provide uniform light distribution. Here, medium sized units have the advantage, and 60-watt and 100-watt tungsten lamps have been used successfully.

For bays of 40 to 60 ft., in height, 500-watt tungsten lamps may be used. For intermediate ceilings from 12 to 18 ft., in height, lamps of the 100 to 400-watt sizes seem best adapted.

Mounting Height of Units Above Floor.—In factory work the mounting height of lamps will often be governed by the details of building construction and the interference of cranes.

All units should be mounted so as to be out of the range of vision. This condition may be interpreted in several ways. The glare from lamps will not be so noticeable to workmen who constantly look down at their work, as when the eye is for the most part directed along the horizontal. Again a small lamp in the line of vision will not be so annoying as a large one. One solution, when the lamps must necessarily be mounted low with respect to the floor, will be to use smaller lamps in larger numbers.

Glare is probably of less importance in factory work than in offices, but is harmful nevertheless. The glare from rays of excessive brightness should be avoided because it lowers the sensitiveness of the eye. The intensity of the illumination on the work, while possibly sufficiently high under other conditions with lamps properly placed and shielded, may seem to be insufficient, due to this reduction of sensitiveness. From the physical standpoint, the effect of glare and the subsequent eye strain is an evil, and it is evident that a workman to be of the most value, should be surrounded by the most advantageous conditions for promoting rapidity and accuracy in his work.

Illumination of Vertical Surfaces.—Another important feature connected with the mounting height is the furnishing of light at an angle, so as to illuminate the side of the tool or piece of work. The point at which the tool is making a cut may require light from an angle rather than from a point directly overhead. For a given spacing of lamps, the higher they are mounted, the more concentrating must be the reflector to produce the highest efficiency of horizontal illumination on the working surface. This illumination on the horizontal surface may not, however, be the greatest feature of importance. One way to secure more illumination on the side of machines is to lower the lamps and use more broadly distributing reflectors, so that the light is directed sidewise as well as downward. On the other hand, if the lamps are mounted too low, they become objectionable by being in the line of vision when a man looks up from his work. Thus, in one instance where the maximum possible mounting height was 13 ft. 6 in., it was found desirable to place the lamps at this height to avoid glare; the side lighting was secured by using broader distributing reflectors and somewhat larger lamps than ordinarily would have been necessary, thus bringing up the horizontal intensity to the same value as with the more concentrating reflectors and smaller lamps, and at the

same time providing the necessary side light for the vertical surfaces.

Reflectors for Uniform Illumination.—Uniformity of the illumination on the working surface generally refers to the illumination on the horizontal planes, similar to a bench or a table. Uniform intensity of illumination over the entire bench or floor surface of a room is generally looked upon as an advantage in a lighting system, and is sometimes the only factor considered.

Reflectors or shades have been made for two purposes. One object is to shield the direct rays of the lamp from the eyes, the other being to redirect the light from the lamp in the most useful and effective direction. In so far as this scientific side of reflectors is concerned, they are now designed so as to furnish fairly definite results. Rules for the use of such reflectors call for a certain relation between the spacing of lamps and their mounting height, if uniform downward light over the entire working surface is desired. For example, one type of reflector calls for a spacing of lamps equal to 0.7 of the mounting height

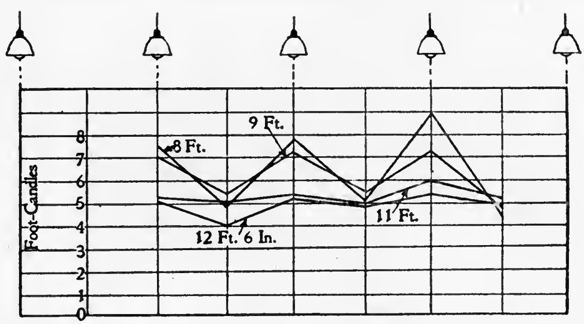


Fig. 134.—Variation in intensity of illumination, with various mounting heights.

above the floor. If this relation between spacing and mounting is followed, uniformity of the illumination on the plane assumed, may be expected, although other effects such as ceiling reflection may tend to vary the resulting intensity. In case this relation is violated by mounting the lamps either higher or lower than called for by rules which consider uniformity of the downward light, the resulting illumination on the working surface may depart very radically from a condition of uniformity.

Test for Uniformity.—The effect on this illumination caused by variations in the mounting heights is indicated by Fig. 134.

The lower curve, marked with a mounting height of 12 ft. 6 in., shows an approximate uniformity of the illumination. The remaining curves show the effect on the intensity of the illumination at the same locations when the lamps and reflectors are lowered. If, then, uniformity of the illumination is desired, such rules as are indicated by the various reflector companies for the spacing and mounting of lamps for a given reflector, should be adhered to.

Value of Light Ceilings.—With a light ceiling, the reflection of that portion of the light which passes through the reflector to the ceiling, and which is added to the light directed downward from the reflectors, is a factor in building up the intensity of the illumination on the working surfaces. In a case of this kind uniform illumination is obtained by the use of almost any reflector whether designed for the purpose or not, provided the lamps are fairly close together. In fact, tests indicate that if lamps without any reflectors whatever are installed in a room with a particularly light ceiling, fairly uniform illumination will result. Under such a condition, however, the bad effect of the unshielded lamps will call for reflectors of some kind. It should also be stated that while a uniform light distribution may result where no reflectors are used, the intensity of the illumination when measured on the working plane may be increased by as much as 60 per cent., by the use of efficient reflectors. This is due to the utilization of the horizontal rays of light which predominate in the bare tungsten lamp, whereas the most effective light rays for factory work are those which are directed downward.

Lighting Circuits.—The matter of suitable lighting circuits is an important consideration. Some units are adapted to direct current only, others operate most favorably with certain frequencies of alternating current. All units to be most effective should be supplied with constant voltage. In factory work, the power load will nearly always be found to exceed that for lighting. With the lighting and power circuits separate, it is easier to maintain the voltage constant on the lamps.

Switch Control.—The switch control of the lamps in any lighting system is of importance, especially where large numbers of small or medium sized units are used. That method of controlling the lamps is most economical in which the interest, depreciation, and maintenance involved in the first cost of the

installation of switches and their attendant wiring, does not exceed the cost of the energy saved by their use in being able to turn out the lamps which are not needed. Too great refinement in the placing of switches may result in a first cost in excess of the saving through their use. Particularly is this the case where the factory receives little daylight, artificial light being required at all times. Here, if the number of workmen is great, practically all the lamps will be needed all the time, and too great refinement in switch control is not warranted. In practice, however, it will usually be found advisable to install a considerable number of switches, as their cost is low in comparison with that of the energy saved by the ability to turn off the lamps in sections when not needed.

Placing of Switches.—One item of considerable importance in large installations is the placing of switches at uniform places; that is, if located on columns, the switches should be placed

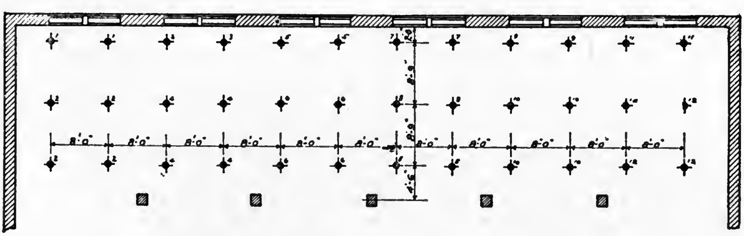


FIG. 135.—Typical working plan for wiremen.

on the same relative side of each, and on columns located on the same side of the aisle. A fairly safe rule is to control the lamps in rows or groups parallel to the windows or skylights. This will be evident by reference to Fig. 135, where the switching is indicated by numerals adjacent to each lamp. Those lamps away from the windows will be required in many cases when the work nearer the windows is still sufficiently illuminated by daylight. If lamps are controlled in rows perpendicular to the windows, all units in a row will necessarily be on at one time, when often only a portion is needed.

The Working Drawing.—A complete self-contained working drawing of the proposed arrangement of lamps will contribute to the ease of installing a lighting system throughout a factory. Such a drawing should be intelligible to the average wireman. It should give the outline of the floor space to be lighted and

should designate the light units in some clear and distinctive form, located to scale as in Fig. 124, a typical working drawing that has been found to give satisfaction in its details. This drawing gives the dimensions of the floor space, distance between lamps and the distances between walls and lamps. The specifications should contain the number and type of lamps, the number and style of reflectors, the number and type of shade holders, and the mounting height of socket above floor. The method of switch control is perhaps most easily shown on the drawing by placing the same numeral adjacent to all lamps to be controlled from a given switch. It will be found advantageous to furnish the maintenance and wiring departments with blue prints of such a drawing.

Maintenance Problems.—The foremost item connected with the operation of a factory lighting system is its systematic maintenance. To furnish the best results a lighting system should be maintained with the same care which attended its installation. The factors which go to make up the maintenance include renewals of incandescent lamps and the cleaning of reflectors and shades.

First of all, if the factory is sufficiently large to warrant it, there should be an organized maintenance department for looking after this work. This department should possess an accurate record of every lamp in the factory and its type. Arrangements should be made for carrying in stock a sufficient supply of repair parts and renewals. It is important that a record be made of all such repairs as well as of the renewals, together with the labor involved. These records will show the maintenance cost of the various units and will serve to indicate if this expense is excessive, due to abnormal conditions in the circuits, in the handling of the lamps or otherwise. In lamps possessing mechanism repairs are necessary, and the trimming of arc lamps is the large item to be charged to a system in which they are used.

The designing engineer may be of service in preventing excess maintenance by seeing that the lamps are so located that the renewals may be easily made. A practical instance will indicate how the maintenance may be affected by the method of installing the lamps. In buildings of open steel construction, so-called stringer boards are often placed between girders, as lamp supports. If these boards are not of sufficient strength to support a ladder, renewals and cleaning of lamps will be difficult. The

higher expense for providing boards of sufficient size will be offset by the greater ease in making renewals, thus reducing the maintenance expense.

Cleaning Reflectors.—The cleaning of glass reflectors is an important item. The depreciation of the efficiency of reflectors of all kinds due to the accumulation of dust and dirt is large. The proper time to clean reflectors is when the value of the light lost, due to dust and dirt accumulations, equals the labor and material cost of cleaning them.

In order to realize the best results from such a maintenance department it is desirable that all lighting installations be inspected once a day. An inspector making his rounds, should report all lamps out of service, together with the number of lamps missing or otherwise in need of repairs. This information embodied in a report and furnished to the maintenance department in such form that all defective lamps can be located quickly, will permit of promptly replacing such lamps, and will furnish at the same time a valuable record for calculating the maintenance costs.

Cost Comparisons.—Cost figures should not be permitted to stand alone, but should be weighed with a due consideration of the usefulness of the light as an invaluable accompaniment of quality and quantity of work produced in a given time. If the factory manager can gain something of this attitude to the lighting question, viewing the matter as an asset to factory production, and will study the kind and quality of light most suitable to each condition of work, better results may be expected than when all attention is fixed on slight differences in first cost or annual charges.

Certain illumination data, which has been taken from actual installations in a factory, is shown in Table XXIII. The information contained in this table is not intended to serve as a rule for factory work in general, but may be used as a guide in other locations where the ceiling heights correspond and where surroundings are comparable.

TABLE XXIII.—EXAMPLES OF FACTORY TUNGSTEN LIGHTING SYSTEMS[1]

Ceiling or girder height	Mounting height above floor	Spacing distance	Size of lamp	Watts per square foot	Class of work and character of surroundings[2]
8 ft. 1 in.	7 ft. 6 in.	8 ft. 0 in. × 8 ft. 0 in.	60	0.94	Detail work, light ceiling, no walls.
9 ft. 0 in.	8 ft. 6 in.	8 ft. 0 in. × 8 ft. 6 in.	100	1.47	Bench work, flat, no ceiling, dark walls.
11 ft. 1 in.	10 ft. 3 in.	8 ft. 0 in. × 8 ft. 9 in.	100	1.43	Bench work, no ceiling, dark walls.
11 ft. 9 in.	11 ft. 0 in.	8 ft. 0 in. × 9 ft. 6 in.	100	1.32	Machining, dark ceiling, no walls.
11 ft. 9 in.	11 ft. 0 in.	8 ft. 0 in. × 8 ft. 9 in.	100	1.43	Machine work, dark ceiling, and walls.
12 ft. 0 in.	11 ft. 3 in.	8 ft. 0 in. × 8 ft. 0 in.	100	1.56	Machine work, dark ceiling, no walls.
12 ft. 0 in.	11 ft. 3 in.	7 ft. 0 in. × 8 ft. 0 in.	100	1.78	Machine work, dark ceiling, no walls.
12 ft. 0 in.	11 ft. 3 in.	7 ft. 0 in. × 8 ft. 0 in.	100	1.78	Bench work, dark ceiling, no walls.
12 ft. 6 in.	12 ft. 0 in.	8 ft. 0 in. × 10 ft. 0 in.	100	1.25	Machine work, dark ceiling, no walls.
13 ft. 8 in.	12 ft. 10 in.	8 ft. 0 in. × 8 ft. 6 in.	100	1.47	Machine work, dark ceiling and walls.
16 ft. 0 in.	14 ft. 6 in.	8 ft. 0 in. × 8 ft. 9 in.	100	1.43	Detail work, no ceiling, dark walls.
16 ft. 0 in.	15 ft. 2 in.	8 ft. 0 in. × 10 ft. 0 in.	100	1.25	Rough work, no ceiling, light walls.
16 ft. 0 in.	15 ft. 2 in.	11 ft. 6 in. × 16 ft. 0 in.	250	1.36	Painting machines, no ceiling, light walls
16 ft. 0 in.	15 ft. 2 in.	10 ft. 0 in. × 12 ft. 0 in.	250	2.08	Fine die work, no ceiling, dark walls.
16 ft. 0 in.	15 ft. 2 in.	13 ft. 0 in. × 14 ft. 0 in.	250	1.37	Bench work, no ceiling, dark walls.
24 ft. 9 in.	21 ft. 3 in.	10 ft. 0 in. × 12 ft. 0 in.	250	2.08	Fine assembly work, dark ceiling, no walls.
24 ft. 9 in.	21 ft. 3 in.	10 ft. 0 in. × 12 ft. 0 in.	250	2.08	Machine work, dark ceiling, no walls.
24 ft. 9 in.	21 ft. 3 in.	10 ft. 0 in. × 12 ft. 0 in.	250	2.08	Testing, dark ceiling, no walls.
25 ft. 2 in.	21 ft. 7 in.	10 ft. 0 in. × 12 ft. 0 in.	250	2.08	Testing, dark ceiling, no walls.

[1] The installations here referred to are not in general provided with drop lamps, the lamps overhead being sufficient for nearly every occasion.

[2] In factory construction, manufacturing spaces often occur where the girders and columns form the boundary lines without walls. Similarly open girder construction often occurs, where no ceiling exists between the floor and the roof.

A Typical Factory Lighting Problem

As a typical example of factory lighting in which many applications of the principles previously stated are in evidence, a factory building will be considered which contains more than 225,000 sq. ft. of floor space and in which over 3000 tungsten lamps have recently been installed. This building, a plan of which is shown in Fig. 136, consists of eight floors, mostly devoted to the manufacture of small machine parts. The walls are light in color and the building has the advantage of a light ceiling. The height from floor to ceiling is 13 ft. 6 in. and the build-

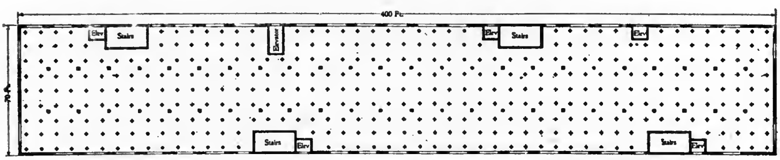


Fig. 136.—Arrangement of lamps. One floor of factory building.

ing is divided into bays of 16 by 70 ft. The work may be classified into bench work, requiring in many cases good illumination on vertical surfaces; machining work, where line shafting and belting form an obstruction to the light; assembly work, often performed on the floor where illumination on the horizontal, inclined and vertical surfaces is imperative; and a storage warehouse, where low intensity is sufficient.

The ceilings are of wood and hence wooden moulding was advantageously used. Switches were placed on central columns, on the same side of the aisle throughout and on the same relative side of each column wherever possible. In feeding the switches, iron conduit was run down the cement columns, and iron outlet boxes served the double purpose of supports for the snap switches and of wall receptacles as outlets for extension lines when required.

Lighting Requirements.—The requirements for the lighting in this building may be enumerated as follows:

1. Sufficient general illumination for all ordinary purposes.
2. Intensities of illumination higher in some locations than others.
3. Higher intensities predominating on horizontal surfaces in certain sections.

4. Sufficiently high intensities on vertical surfaces.
5. Glare reduced to minimum.

One of the very trying conditions was that of providing sufficient illumination for the classes of work where varied intensities were necessary, and at the same time maintain a uniformity of installation and distribution of illumination, so that work could be done with equal ease at any portion of the floor space. This feature was taken care of by providing outlets with standard spacings all over the building except in the warehouse and storerooms, and by varying the intensity where necessary by a change in the size of the lamps. It will be seen that this is an excellent feature of a distributed system of lighting, since a change in the size of the lamps and reflectors in no way changes the uniformity or the distribution characteristics of the resulting illumination.

Experiments and Steps Leading to Final Arrangement.—As a first step several bays on one of the floors were equipped with 100-watt tungsten lamps spaced 8 ft. apart and 2 ft. 6 in. from walls, the lamps being mounted at the ceiling. This size of lamp seemed best adapted to the ceiling height, and the size of bay was not only very suitable for this spacing (since eighteen lamps filled one bay) but the arrangement was symmetrical with respect to the bay itself. The ratio of spacing distance to mounting height called for concentrating reflectors, which were installed along with bowl-frosted lamps. Several adjoining bays were equipped with lamps of the same size but with different types of reflectors, both glass and metal. These trial bays were left in service for several months so that the opinions of all concerned, including the workmen, could be obtained, and also for the purpose of making tests and noting the effect of dust and dirt on each type of reflector. Six lamps were controlled per switch, thus requiring three switches per bay, all three switches being mounted on one column. A trial was also made of several bays with bare lamps to note whether the resulting illumination was noticeably less than that with reflectors. It was thought that the shielding effect of the girders might serve as a sufficient protection for the eyes of the workmen without the addition of shades or reflectors. Furthermore, various mounting heights and various shapes of reflectors were tried for the purpose of investigating the proportionate relation of downward and side light. The same procedure was also tried with other

sizes of lamps and reflectors so as to determine whether the size nominally selected was most suitable for the purpose.

Notes on Final Arrangement.—The main results from these experiments, covering several months, were as follows:

1. **Size of Lamps.**—The 100-watt lamps seemed the best average size, but at least two intensities were found advisable, one somewhat high for detail and machine work, and a lower intensity for assembly work.

2. **Mounting Height.**—Of the various mounting heights tried, it was found very desirable to mount the lamps as close to the ceiling as possible, so that glare was reduced to a minimum.

3. **Number of Lamps per Bay.**—The general scheme of installing eighteen lamps per bay seemed best.

4. **Arrangement of Switches.**—The switching of six lamps per circuit, while possessing some good features, did not seem a sufficient sub-division. At times, the work directly next to windows was sufficiently lighted by daylight, while the work under the second row of lamps was not. This led to the conclusion that the lamps next to the windows in each bay should be on one switch, and four lamps per switch in general seemed a better arrangement than six.

5. **Depreciation Due to Dust.**—It was found after several months of service, during which time the reflectors were allowed to remain uncleaned, that tests on each of the reflectors before and after cleaning indicated about the same degree of reduction in efficiency. It was noted, however, that reflectors located near belting became covered with dirt in very much less time than when the lamps were in a clear open space.

6. **Intensity of Illumination on Other than Horizontal Surfaces.**—While the ratio of spacing distance to mounting height of the lamps called for a concentrating reflector for producing uniform downward light, a distributing reflector was essential to provide side light. An intensity of about two foot-candles on the sides of machines seemed to be sufficient. For reasons previously stated, in certain portions of the building the reduced intensities of the illumination on the horizontal surfaces, owing to distributing reflectors being used, which directed a larger proportion of the light upon the vertical surfaces, was made up by the use of higher candle-power lamps than originally contemplated.

7. **Bowl-frosted versus Clear Lamps.**—Bowl-frosted lamps proved not so desirable as clear lamps, due to the more rapid

effect of dust and dirt on the frosting. This effect is, of course, particularly noticeable in factory work.

8. **Metal versus Glass Reflectors.**—Metal reflectors in these locations were far inferior to glass because no light passes through them. Glass reflectors, on the other hand, permit some of the light to pass through the reflectors, which in turn is reflected from the light ceiling and walls.

9. **Advantages of Reflectors.**—Lamps without reflectors were debarred on account of the glare which resulted when a man looked up from his work and further, since 62 per cent. more illumination was delivered, on the working surfaces by lamps equipped with reflectors than with bare lamps of the same size. It was considered a good investment from these two important standpoints, to provide all lamps with the most efficient reflectors available, conclusive tests showing very clearly that cheap ones rarely justify their cost.

Some Comments on This System.—This tungsten lighting system has now been in service long enough to indicate that for a majority of the work in this building, the illumination facilities are unusually satisfactory. Experts have viewed this lighting arrangement and have expressed the opinion that this particular factory is one of the best lighted buildings in the country, bringing out many valuable points in recent illuminating engineering practice. A great many individual lamps were used previous to the new lighting system, and it was thought by workers and foremen that these lamps would have to be left in service notwithstanding the new overhead lighting installation; practically all individual lamps were taken out, however, with the understanding that they would be put back after several weeks if found necessary. The object has been to give a sufficiency of light to every workman, and it was found that a very much less number of individual lamps were called for than were formerly thought to be necessary. Here and there a drop lamp has been installed to take care of some special work requiring light at an unusual angle or of more than ordinary intensity; but as an evidence of the acceptability of the new light, it may be stated that during the past winter since the new system has been installed, the complaints and calls for changes in the wiring have been negligible, compared to the extreme number of similar complaints during the preceding winter when a system of inferior

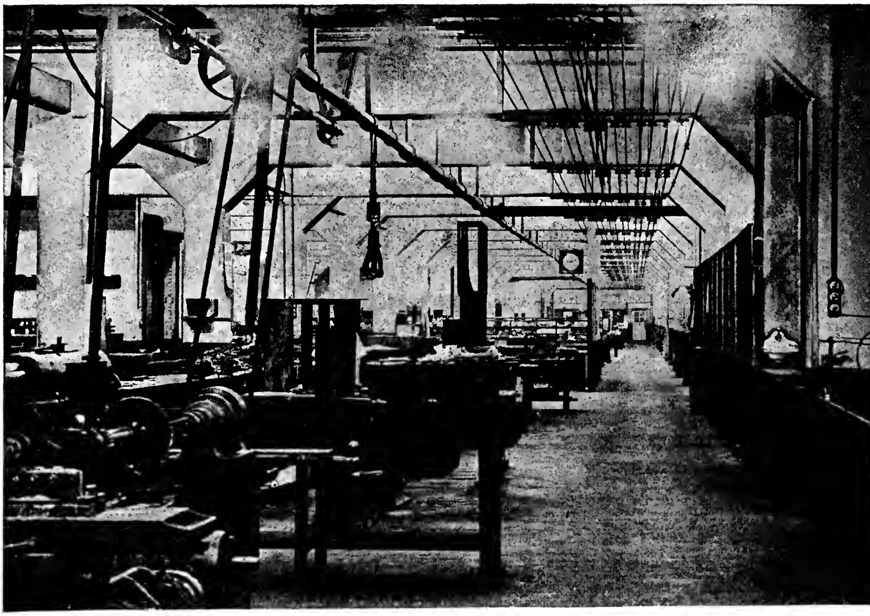


FIG. 137.—Shop interior lighting.

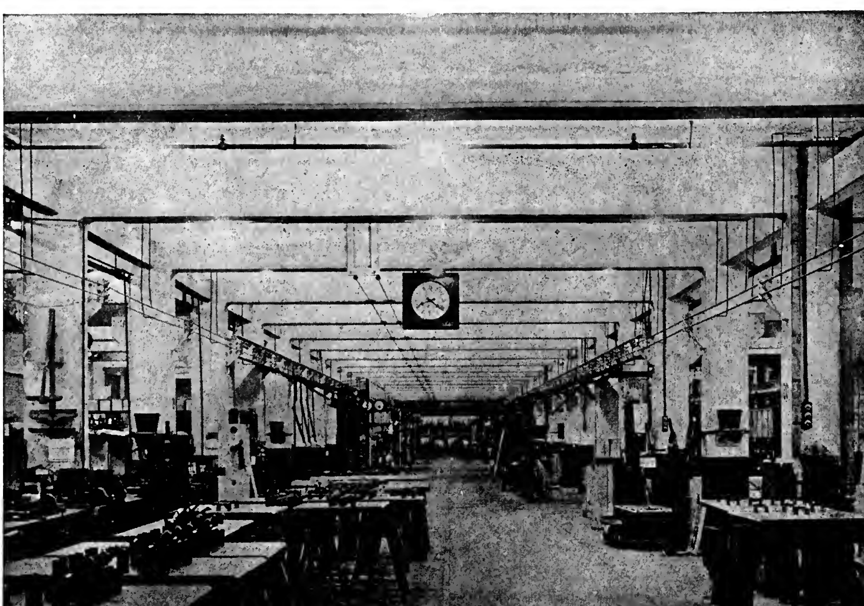


FIG. 138.—Shop interior, well lighted.

lighting was in service. This fact in itself is an unquestionable recommendation of the new lighting system.

One point of interest in connection with this lighting installation is that the final arrangement was the outcome of experience rather than predetermination. Months of careful investigation and trial were made of the various schemes as indicated in the preceding notes, and the completed work was chosen, on a basis not only of these tests, but also on the opinions of those who were to work under the lighting. Theory and formula give a general basis, but often fail to take account of certain practical conditions. For example, the reflection from ceilings and walls; the color of machinery or materials; the need for numerous lamps of smaller size to prevent shadows which are unavoidable with high candle power units, and the allowance to be made for dust and dirt on lamps and reflectors, are points which show why many things must be considered, aside from the mere area to be lighted, if satisfactory results are to be assured.

CHAPTER XXIII

DRAINAGE OF INDUSTRIAL WORKS[1]

The drainage of industrial plants may include not only the drainage of the individual buildings, but the arranging and laying of a complete system of sewers, the importance of the latter being proportionate to the whole undertaking. As so many manufacturers are now erecting new works on suburban or rural sites, where abundant opportunity exists for expansion, the importance of drainage is increased. In such cases, the laying out of a sewerage system differs but little from that for a small town or village, and this condition is assumed in the following pages.

The science of sanitary engineering is of late origin, for not until the middle of the nineteenth century did the people fully realize that their lives were, to a great extent, in their own hands, and that many, if not the majority of deaths might be avoided. The application of sanitary drainage to manufacturing plants is still more recent, for most of the old style factories had only the crudest accommodations in this respect.

In this connection one writer says, "If the air is vitiated, water rendered impure, or food improper or insufficient, the body is robbed of life-giving elements and soon succumbs to disease and death. It is the true aim of the sanitary engineer to assist nature in her great but simple operations, to facilitate the purification of air, to prevent dangerous impurities entering our supplies of water, to furnish an abundance of these life-giving elements, and to remove as speedily as possible before decomposition commences all those matters eliminated from animal bodies, together with all decomposing refuse."

The study of sanitary drainage is essentially one of life, for health and longevity are natural, while disease is abnormal, death, except from old age, is accidental, and both are to a large extent preventable by human agencies. But no sooner do human beings begin to live and work in one place, than danger

[1] H. G. Tyrrell, in *Municipal Journal and Engineer*, May, 1901.

from decomposing refuse begins. As hamlets increase to villages, and these again to towns and cities with the many and crowded workshops, the danger becomes greater. Hence from the first it is important that the greatest attention should be given to the drainage of the place.

During twenty-two years of continuous war on the continent, England sustained a loss of 79,000 men, but in one year of cholera her loss was 144,000. In the British army before sanitary improvements had been installed, the death rate was one in forty-two, with two sick men out of every five picked and able-bodied men. But after a more perfect system had been provided, the death rate was only one in one hundred and forty-three, with one sick out of every twenty-one. Epidemics of disease are too often ascribed to "an act of Providence to whose ruling all must submit, but looking with the eyes of science upon the overflowing cesspools and reeking sewers as inevitable causes, and with the eye of humanity upon the interested and innocent victims languishing in pain and peril, or mouldering in their shrouds, such implications of Providence, though perhaps sincerely made, are next to blasphemy, especially when uttered by the agents who are responsible, though the prayer of charity might be, "Father forgive them for they know not what they do."

The Drainage of Buildings.—The final object of any system of sewers however elaborate or complicated, is the drainage of buildings. In order that this drainage may be complete, the following requirements should be kept in view:

1. The foundation soil shall be free from dampness.
2. All liquid and excremental waste shall be safely and quickly conveyed beyond the building limits.
3. A constant supply of pure air shall be admitted.
4. Nothing shall be allowed to collect about the place which would taint the air or render the atmosphere impure.
5. Proper arrangement must be made to prevent the entrance of sewer gas through traps or other fixtures.

The first of these requirements, that the subsoil be free from moisture, is of great importance. If a basement or cellar is always damp, and gases are continuously rising through the shops, it is impossible that the occupants be hale and strong. If the foundation is of gravel or sand, no other drainage is necessary. But where clay occurs, as is usually the case, a 2-in. drain all

around just inside the wall and about a foot or so from it, will be needed. Similar ones should be placed at distances apart of about 15 ft., crosswise of the building. To prevent the exhalation of moisture which rises even the driest soil, a coat of some impervious substance such as dense concrete, asphalt or hydraulic cement should be spread.

Perhaps the most difficult of all in this connection is the arranging of pipes and fixtures for the removal of waste. If the pipes are of lead their durability will be much increased by giving them a thick coat of paint inside, and when thus protected and well ventilated, they should last from twenty to thirty years. Iron pipes are sometimes used and they are usually screwed together, thus being strong enough to support their own weight with the help of straps. Around the joints spherical covers are sometimes placed, so that a slight settling of the pipes will not break the connection.

The essential features in the arrangement of waterclosets, sinks, etc, are:

1. Extension of all soil and waste pipes through, and above the roof.
2. Provision of fresh-air inlet in the drain, at the foot of the soil- and waste-pipe system.
3. Trapping of the main drain outside of the fresh-air inlet.
4. Placing of each fixture as near as possible to it, with a self-cleansing trap, safe against siphonage and back pressure.
5. Locating of vent pipes to traps under such fixtures as are liable to be emptied by siphonage.

Thus by having a ventilation at both ends of the soil pipe, the accumulation of foul gases is prevented, which would very soon destroy lead pipe. Without this ventilation, traps are always liable to be forced or siphoned, owing to the force of tides or winds at the mouth of sewers, or to a change of temperature.

While the fresh-air inlet at the foot of the soil pipe is beneficial as a ventilator, it is obnoxious on account of emitting gas. Waste pipes from sinks should have traps outside the building near the wall, to catch oily matter before it hardens. Catch basins may be made of brick or concrete about 4 ft. in diameter, with pipes arranged to siphon when the chamber is full. If the catching of grease is not the object, a flush tank may be substi-

tuted. When the tank is full, one more flow of water into it starts the siphon acting which empties it nearly to the bottom. In some cases, slops may be disposed of by carrying them

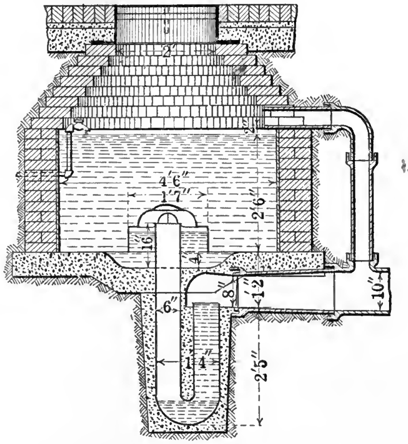


FIG. 139.—Siphon tank.

through a system of pipes with open joints, laid underneath some adjoining farm land or meadow. Before entering the open drains, the water passes through a flush tank, making the

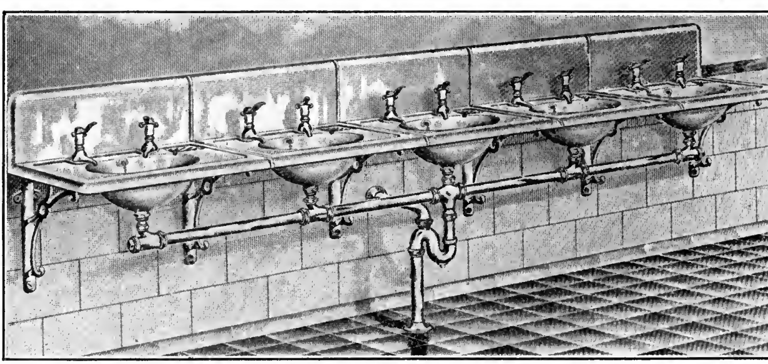


FIG. 140.—Line of wash bowls.

discharge intermittent, and the flow of water being more copious, saturates the ground to a greater distance.

Waterclosets are the most troublesome of all plumbing arrangements. It would be well if they were built separate al-

together from the main buildings, but as this would to a great extent destroy their convenience, they may be separated from the shop by a ventilated lobby or by double doors, and they should always have outside windows. The most approved arrangement is to place all toilets in a single room on each story, or to group them all in one story, usually the basement or the upper floor. Fixtures should be extra heavy as they often get rough usage. Enough wash bowls (Fig. 140) should be provided so there will be at least one for every three people in the building, and not less than one toilet for every twelve persons. Enameled iron ware is so much cleaner than any other, that it should in-

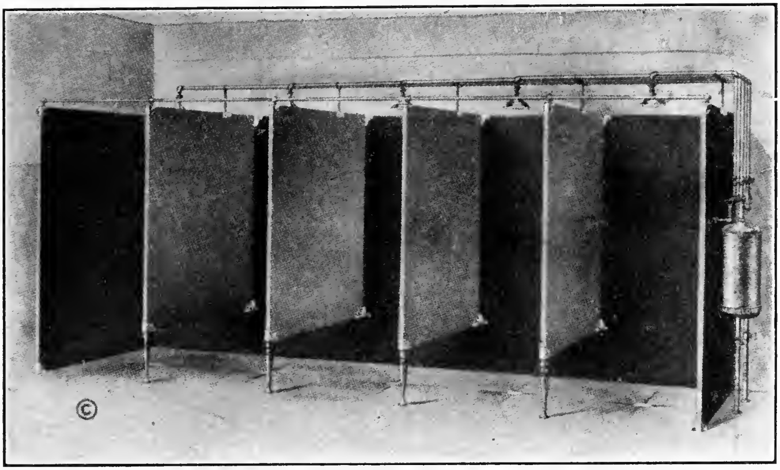


FIG. 141.—Cluster of showers.

variably be used, and wood excluded. Foundries are especially in need of efficient wash rooms, and in some cases, one bath room is provided for each workman. In some states, the law requires that foundries shall have shower baths (Fig. 141) and full provision for the comfort and cleanliness of operatives. These rooms should be in charge of an attendant whose duty it is to keep them clean. The walls and floors should be of cement or tile, so a hose can be used for washing. A room for the storage of clothing should adjoin the wash room, and this should have individual lockers with perforated sides for ventilation, metal ones being preferred.

Watercloset fixtures (Fig. 142) are made in great variety, and

most of the large manufacturers will forward their catalogues to prospective buyers on request. Many fixtures are made especially for factory use, and as a description of them would fill a whole book, it is impossible to even mention the good points which are obtainable. They should have a tight valve and a double water seal, with water enough under the seat for immediate disinfection. Many sanitary authorities prefer the simple hopper closet, since its only trap is always in sight. Where an intermittent water supply of about fifteen minutes is provided, it is perhaps the best. Two types of urinals are shown in Figs 143 and 144.

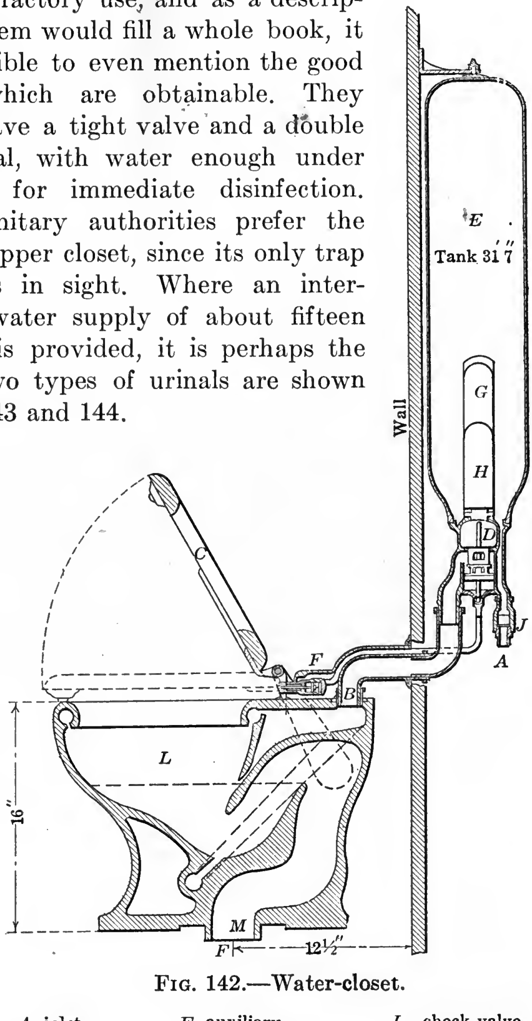


FIG. 142.—Water-closet.

A, inlet	*F*, auxiliary valve	*J*, check-valve
B, outlet	*G*, inner chamber	*L*, bowl
C, seat	*H*, float	*M*, bowl outlet
D, valve		
E, tank		

The Drainage of Plants.—When building new plants in rural or suburban places, it is often necessary to design a sewerage

system extensive enough to include not only the plant itself, but the whole industrial village, and for this reason a discussion is given of the drainage of the yards and entire site.

Sewers were originally for surface drainage only, and it was then unlawful to discharge refuse or foul matter into them. But in 1847, this idea seems to have been reversed, as an act of Parliament made it compulsory for all drainage in cities and towns in England to be discharged into the public sewers. They

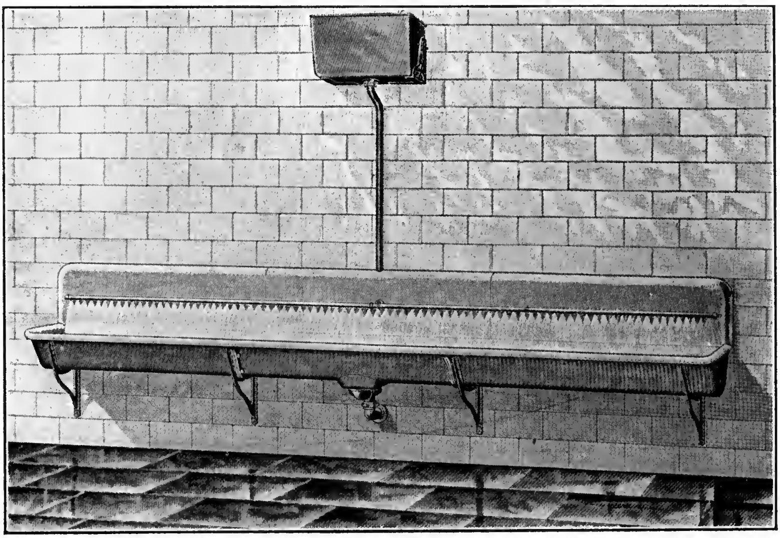


Fig. 143.—Trough urinals.

must be of the proper size with sufficient fall, and means should be provided for flushing them. A system of sewers should be perfectly tight from end to end, for if they allow foul liquids and gases to permeate the ground, they are no better than vaults or cesspools.

In starting to lay out a system of sewers for a manufacturing plant or industrial village, even though it is not intended to complete the whole of it at first, a plan should be made showing the final creation, so that when it is ended, the arrangement will be in accordance with the original design.

The fall or inclination of sewers is important, and the following table gives the proper grades for those running either full or half full.

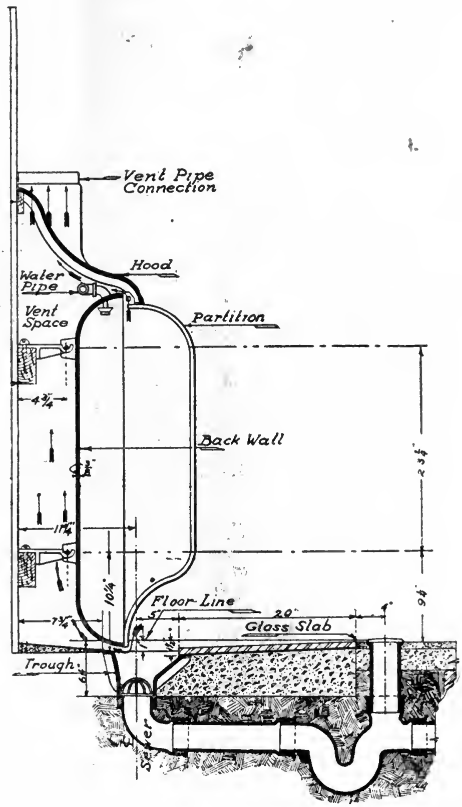


FIG. 144.—Plan of separate urinals.

6-in. pipes.	Grade 1 in 60
9-in. pipes.	Grade 1 in 90
12-in. pipes.	Grade 1 in 200
15-in. pipes.	Grade 1 in 250
18-in. pipes.	Grade 1 in 300
24-in. pipes.	Grade 1 in 400
30-in. pipes.	Grade 1 in 500
36-in. pipes.	Grade 1 in 700
48-in. pipes.	Grade 1 in 800

When the direction changes, the friction increases and the fall must be greater. The most rapid fall should be given at the upper end of the sewer where the quantity of water is least and consequently where the velocity is needed to start the flow. Instances are known in which inaccuracies of 1/16 to 1/8 in. in the grade of sewers rendered them inefficient and necessitated their removal, but in such cases the inclination was very small, not exceeding 7 or 8 in. per mile.

If the amount of water flowing is proportional to the size of the conduit, sewers of different sizes give the same velocity at different inclinations. For example, a 10-ft. sewer with a fall of 2 ft. per mile; a 5-ft. with a fall of 4 ft. per mile; a 2-ft. with a fall of 10 ft. per mile; and a 1-ft. with a fall of 20 ft. per mile, will all have the same velocity, but the 10-ft. sewer will require 100 times as much sewage as will the 1-ft. sewer and unless it carries a volume of water proportional to its capacity, the velocity of its stream will be correspondingly lessened. It becomes, therefore, especially important that the size of the conduit be adjusted to the volume of the stream. When half full and when full, the velocity is the same, and when a little more than three-quarters full the velocity is greatest.

In determining the size of a sewer it is necessary to consider not only its fall, but also the amount of rainfall and sewage which it must carry away. The commonest of all defects is that expensive one of being too large. It is much better to have occasional repair after excessive rainfalls, than to provide for extraordinary ones. The invariable result of making a sewer too large is that sediment forms in the bottom and before long it is clogged with filth, or only a small orifice remains large enough for the ordinary flow. Whereas, had the sewer been of proper size at first, it would by its own flow, have been kept clean, and would have received a much greater rainfall than the larger but choked sewer.

In small towns and villages it is not usual to allow for a greater precipitation than $\frac{1}{4}$ in. per hour, but in cities where the area is mostly built over, and water can more easily find its way to the sewers, a fall of $\frac{1}{2}$ in. per hour is allowed. Even in populous towns and cities a considerable quantity of water will not reach the sewer but will soak into the ground or evaporate. Assuming that a fall of $\frac{1}{2}$ in. per hour reaches the sewer, this

is providing for a much heavier fall, probably a total of about 1 in., the average amount of sewage in a town with water supply is about 25 gallons for each person per day, half of which will be discharged between 9 A. M. and 5 P. M.

As a stream flows on, its velocity will increase, and consequently its volume will diminish. Therefore, a pipe running full at its upper end, may receive a large quantity more during its course. A street in London has a brick sewer 5½ ft. high and 3½ ft. wide with a 12-in. pipe laid along the bottom for a distance of 560 ft. This was never known to be choked, and during storms, stones could be heard rolling along the bottom. This pipe is rarely more than half full at the head. The cross-sectional area of all the drains entering it is equal to that of a pipe 30 ft. in diameter. Although the 12-in. pipe is always clean, the large brick sewer is constantly collecting deposits of filth, 20 or 30 ft. from where the small one joins it, which deposit must be removed by expensive hand labor. Instances have frequently occurred where workmen, by mistake, have put in pipe as sewers, which the architect intended for a single building, and the result has been that they were always clean and served their purpose well.

The round sewer, as a general rule, is the best. With it, good joints can always be made by turning the best fitting parts to the bottom, and they have the greatest area for their perimeter. The pipes should always be hard and smooth, for if at all porous, they contaminate the adjoining ground, and are more subject to frost, and to the destroying action of sewer gases. If there is danger from roots of trees, it is advisable to lay the pipe in cement. Where the supply of sewage is very intermittent, an egg-shaped sewer is sometimes preferred, because when the stream becomes very shallow, it is also narrow, so that sediment is not likely to collect. This shape of sewer is usually made of brick, and is more expensive than pipe.

Ventilation of Sewers.—One writer described the danger of unventilated sewers as being greater than that of a steam engine without a safety valve, for while in the latter case, the lives of only a few are exposed, in the former, the health and life of the whole community is at stake. As temperature changes, tides rise and fall, or the force of the wind at the mouth of the sewer varies, the pressure of the confined gases is also changed, and since the amount of water in ordinary traps is small, they will

probably be forced or siphoned. If siphoned, a direct communication for the entrance of poisonous gases will be established between the public sewer and the building. Besides, if means be provided for a free passage of air through the sewer; the same amount of gas will not be generated, for much of the foul matter in a short time becomes oxidized.

Ventilation by means of water pipes to the eaves of buildings has been advocated, but this method is faulty, in that during heavy rains when most needed, the pipes are choked with a flow of water. Most authorities on sanitation have decided that the best sewer ventilators yet used, are manholes covered with iron gratings, emerging in the center of the street. The charcoal ventilator has also been used with success, for in a city of England where more than 500 of these ventilators were installed, the total yearly expense was less $1.25 for each. The arrangement consists of a special tray covered with charcoal set in the ventilator so that all gases ascending are forced to pass either through or over the charcoal. When it is remembered that 1 in. of charcoal contains as much interior surface as 100 sq. ft., an idea can be formed of its power as a disinfectant. Around the special tray is a box for catching any rainfall or dust which may find its way through the iron grating. These ventilators in order to give thorough satisfaction, should be placed every 200 or 300 yd. apart in the sewer. They should not branch off directly from the sewer, but should rise from a camber of about a foot, so that passing gases will be lead to the outlet. When the street incline is great, a light hanging valve may be placed above each ventilator. This will not obstruct the flow of sewage, but it will prevent gases rising to the higher part of the system, and escaping all from one place or through a few ventilators.

In the city of Windsor, England, in 1856, a case of typhoid fever was discovered. From lack of proper sewer ventilation, the foul and poisonous gases from the fecal matter of this one patient, rising through forced and siphoned traps, caused the death of no less than 450 other persons, all of whose houses without exception were connected with this sewer. Windsor Castle, having its own drain, escaped. In another city, the breaking out of typhoid fever in the higher parts of the town while the lower portions remained untouched was considered a mystery until it was found that the sewers not being properly arranged allowed the poisonous gases to rise to the higher parts of the

system, where they escaped and spread the germs of disease. In this, as in many other cases, the community was stirred to action only by the cruel hand of pestilence.

Flushing of Sewers.—When a system of sewers is faulty either in grade or in size, special appliances for flushing should be provided. One effective arrangement consists of an iron tank fastened on trunnions, having the back end the heavier when empty. On being filled with water and waste, the front end becomes the heavier and it is tilted forward. It is faulty in one respect, that when in a fallen position all matter issuing from the sewer above it, will form a pile of filth beneath the back part of the box. Other arrangements such as dams, etc., have been used, but they are insufficient, since they are not self-acting but require constant attention. Another useful flushing tank for sewers has a disk held in place by the force of the water covering the mouth of the sewer running from the manhole. The sewage is periodically released by means of a chain fastened to a circular block, but as a precaution, a float is attached to the chain, so that, should the water rise to that height, it would liberate itself. If, however, sewers are properly arranged in other respects, they will require but little flushing. During hot summer months or if fever is prevalent, an occasional cleaning will be necessary. The work should always be begun in the lower end, so deposits already there will not stop other wash.

Catch basins should be placed at the corners of the streets or wherever required, for the purpose of arresting silt and solid wash from the streets. In these the iron over the mouth of the pipe leading to the sewer is hinged at the top and is cemented to the brickwork with plaster of Paris, so in case of frost the cement only will be broken, which can be easily repaired in the spring. Many engineers still prefer the method of conveying street wash away in a separate channel. These conduits may be constructed in the form of deep cast-iron gutters covered with a cast-iron grating, the inner edge of the gutter being carried up to the height of the sidewalk. As the accumulated flow requires greater cross-sectional area, it should be made in depth rather than in the width, which will assist in keeping the gutter clean. The chief objection to this method is that in the winter time the crossings become coated with ice, but this difficulty

is no greater than that arising from ice on the sidewalks and about the catch basins.

Pneumatic System.—All the elements have been called upon as aids in the drainage of communities, including water, dry earth and ashes, and now the aid of compressed air is used in removing refuse from buildings. On account of its comparatively recent discovery, this system is but little used, but in Holland and Austria where it has been tried, good results have been obtained. It is to the research and ingenuity of a Dutch engineer that the world is indebted for the discovery of a system which has been declared as the greatest modern invention in sanitary science. It consists in having a number of air-tight iron reservoirs, as many as the size of the manufactory or village needs, sunk to a sufficient depth beneath the surface to prevent freezing, to which are connected the drains from the buildings. These iron chambers at certain intervals are exhausted of their air, so that when valves connecting with the drains are opened, the pressure of the atmosphere forces everything from the pipes down into the central reservoir. If these pipes are numerous, they may all, in the same way, be emptied by a similar process into one central and final vault. The chief difficulty that presented itself in this undertaking was that some pipes would be emptied before the others, in which case the air, finding easy access through the empty drains, would no longer affect those which were still full. But the difficulty was overcome by applying the principle of equal barometric pressure. Before entering the main, each building drain, has a break or abrupt change in elevation of say, exactly 1 ft. If one building drain discharges a large quantity daily and another supplies only a small quantity of sewage, then if the air be extracted from the main so atmospheric pressure acts in both drains, the liquid in the first will descend before that in the second begins to move. Then when they have both reached the same point, the liquid in both will flow out together. In the same way, no matter how great the number of drains, they will all be emptied at the same instant.

The closets were originally simple iron hoppers, placed where possible one above another, so the fall was nearly straight. But other kinds may be used equally well, provided a large size ventilation pipe passes up through the roof by which the atmos-

phere may exert its full pressure on the liquid in the drain. As the sewage at the final depot is run through sieves, and evaporated for use as fertilizer, the street wash and thin slops are usually conveyed by a separate set of pipes into a lake or stream.

The chief advantage of this method above others is that it returns to the soil that which is taken from it, and also the income from the sale of the product soon pays for the extra cost of construction.

Conservation of Sewage.—The earth, given by the Creator to man, was intended not as a store house to be pillaged, but to be judiciously used. With the water system, refuse run into the lakes or ocean is lost, as far as the present era of the world is concerned. If year after year and generation after generation the nourishing properties are extracted from the soil, the inevitable result must be impoverishment. A city of 100,000 inhabitants has a yearly provision supply of about 100,000,000 lb. which is all turned into the sewers and lost. This would produce annually about 5000 tons of dried excrement. The yearly amount of excrement from an average inhabitant is 56 lb., the amount of organic matter in solid dried excrement being 88 per cent. and in urine, 3 per cent. But the total daily amount of organic matter from the latter is about one-third more than from the former. Remembering that five-sixths of the ammonia capable of being generated from human excreta is furnished by the urine and only one-fifth by the feces, and how small is the proportion of the total urine passed at the same time, and that it is impossible to collect all the latter, the intrinsic value of the fertilizing matter which can be practically recovered is probably not more than one-third the value, or amounts to 75 cents per annum for each person, taking the usually accepted value of excreta from an average person as $2.25 per year.

By discharging its sewage into a lake or waterway, a city of 100,000 loses annually no less than $70,000. Assuming the present population of the United States to be 90,000,000, the nation loses annually from this waste $60,000,000 to $70,000,000.

Final Disposal of Sewage.—This is, perhaps, of all problems in sanitary science, the most difficult. Attempts have been made to dispose of sewage by irrigation, ignition, etc., but no complete and satisfactory method seems to have been devised. For

small manufacturing plants or industrial villages and for single factory buildings the problem is comparatively simple, but in large centers where the quantity of solid and liquid refuse is great, it is much more complicated. Sewers cannot discharge into a lake in the vicinity of water works or intake, neither should they run into a stream from which a few miles further down another manufactory or village derives its supply of fresh water.

Perhaps the most successful solution yet presented for the subject is that of irrigation. Experiments show that for this purpose there should be at least one acre of land for each 150 persons. The most suitable soil is a loose gravel thoroughly drained at a depth of about 6 ft. below the surface. The same plot should not be used continuously, for sufficient time should be given at intervals for the ground to become thoroughly aeriated. On being thus exposed to earth and air, all organic particles become so oxidized that the liquid passes off in a comparatively pure state, and may with safety be discharged into a lake or stream. This system requires but little time to pay for itself, for the amount of extra vegetation produced yearly on the irrigated soil has in almost every case been equal in value to a large proportion of the original cost of land and labor.

At Coventry in England, the liquid sewage is rendered harmless by mixing it with sulphate of alumina. The engineer in charge of the works there states in his report that the fluid passing off at the rate of 80,000 gallons per hour was clear and bright, and of a high standard of purity. It was without smell or color and at noon was found to contain only 5.85 parts of ammonia in 100,000 parts. The solid matter from the sewer, after being separated from the liquid, is dried and sold as a fertilizer for the land. In order that the discharge may be more copious various storage tanks have been devised, so that when a flow occurs it will be dispersed over a greater area of land.

Another method of sewage disposal is that of ignition. The precipitated sewage is first run into shallow pits where it is partially dried, after which it is burned in large kilns. This method, although producing no revenue from the waste, and on the other hand creating some expense, has the advantage of immediately and thoroughly destroying the source of disease, which is far

better than storing up evaporated excreta with the expectation of selling it, and the liability of spreading sickness throughout the country.

From the above it appears that large manufactories instead of incurring constant expense for the disposal of sewage can cause it to be a source of revenue, and streams may continue pure and clean instead of being polluted as they so often are with dyes and refuse from shops and mills.

CHAPTER XXIV

WATER SUPPLY AND STORAGE TANKS

The four chief departments of water supply are: (1) The source, (2) the reservoir or storage tank, (3) the pumping equipment, and (4) the distributing pipes and system.

Water for manufacturing plants can be taken either from some established town supply, or independently from an adjoining lake or river, though springs or artesian wells are often used. In some regions such as that adjoining the great watershed of the Mississippi river, or in the western arid states, artesian wells are common, and the depth at which water is found may vary from 100 to 3000 ft. These wells are usually 8 in. in diameter and are lined with wrought-iron pipe.

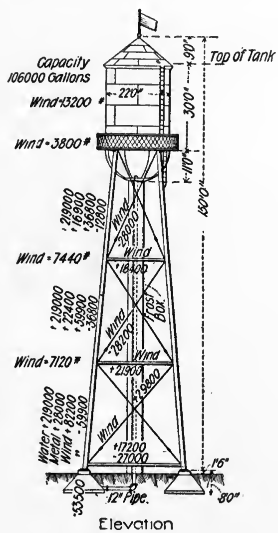


Fig. 145.—Steel water tank and tower at Paris, Ill.

Elevated tanks are valuable not only for regular water service, but for fire protection, especially with automatic sprinkler systems which should always be connected to two separate water sources. Even in towns and cities with adjoining fire hydrants, insurance rates are greatly reduced by the presence of a private pressure tank. These were formerly made exclusively of wood and are now to a great extent, but as they rarely last more than twelve to fifteen years, they are being replaced by steel. They may either be at ground level or elevated on a tower, the latter being most effective when only a limited water supply is needed, for their whole contents is then under a higher pressure than if standing on the ground. Some designs are illustrated in Figs. 145, 146, 147 and 148, the last being of concrete. Fig. 149 is the detail of a tank roof.

The number of tower legs should be proportional to the size of tank, large ones requiring a greater number than smaller ones. By far the heaviest and most expensive part of framed water towers is the platform under the tank, where very heavy beams are often needed, but this expense may be reduced by using a spherical bottom.

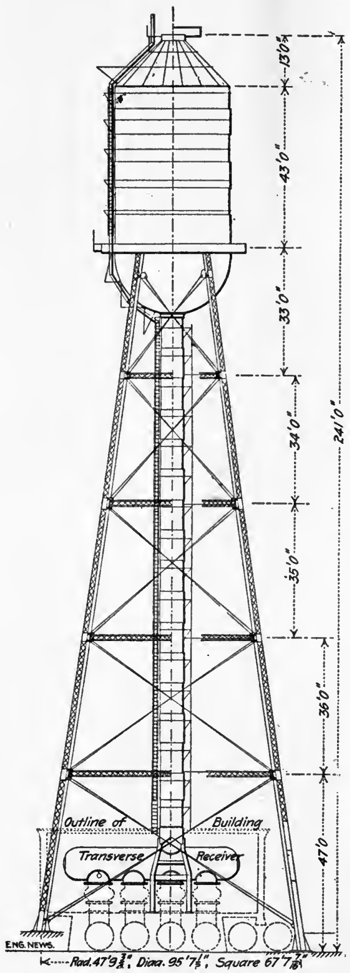


FIG. 146.—Water tank and tower, Great Northern Power Co. Height 241 ft.

They must be strong enough to resist the pressure of water, a cubic foot of which, containing 7.48 gallons, weighs at 62° F. 62.36 lb. A gallon of water containing 231 cu. in., weighs 8.33 lb., and a pressure of 1 lb. per square inch therefore results from a depth of 2.31 ft.

The problem of water supply may be comparatively simple in regions near the coast with large precipitation, but in arid countries it is often perplexing, and the little water that can be found must be collected and stored. In the Eastern or Middle States, small streams may often be dammed at two or three points, thus forming ponds or storage basins of fresh water, but streams are not always available and other methods must be sought.

In order to show some of the conditions in the arid states, and the methods of overcoming them, a brief account is given of the investigations and plans made by the writer for supplying and storing water for railroad shops and locomotives, at a small town in Nevada on a main line of railway.

The old but insufficient water supply came from a small reservoir on rising ground about a mile north of the railway

depot. The surface of this reservoir was 22 ft. above the base of rail at the old water tank, and from this reservoir a 10-in. riveted iron pipe brought water down by gravity to a 30,000 gallon wooden tank located about 700 ft. from the depot. This

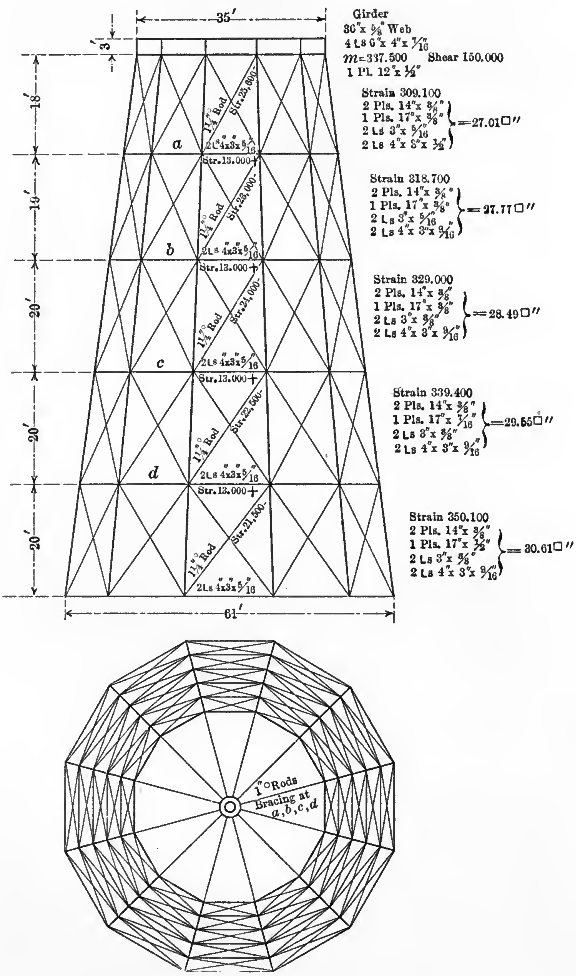


FIG. 147.—Tower for water tank.

tank stood on wooden posts and the highest water in it was $20\frac{1}{2}$ ft. above the base of rail. It was used not only for supplying locomotives, but for the workmen's houses and a few fire hydrants.

On account of increased travel on the railway, and the building of large new shops and round house, as well as for additional

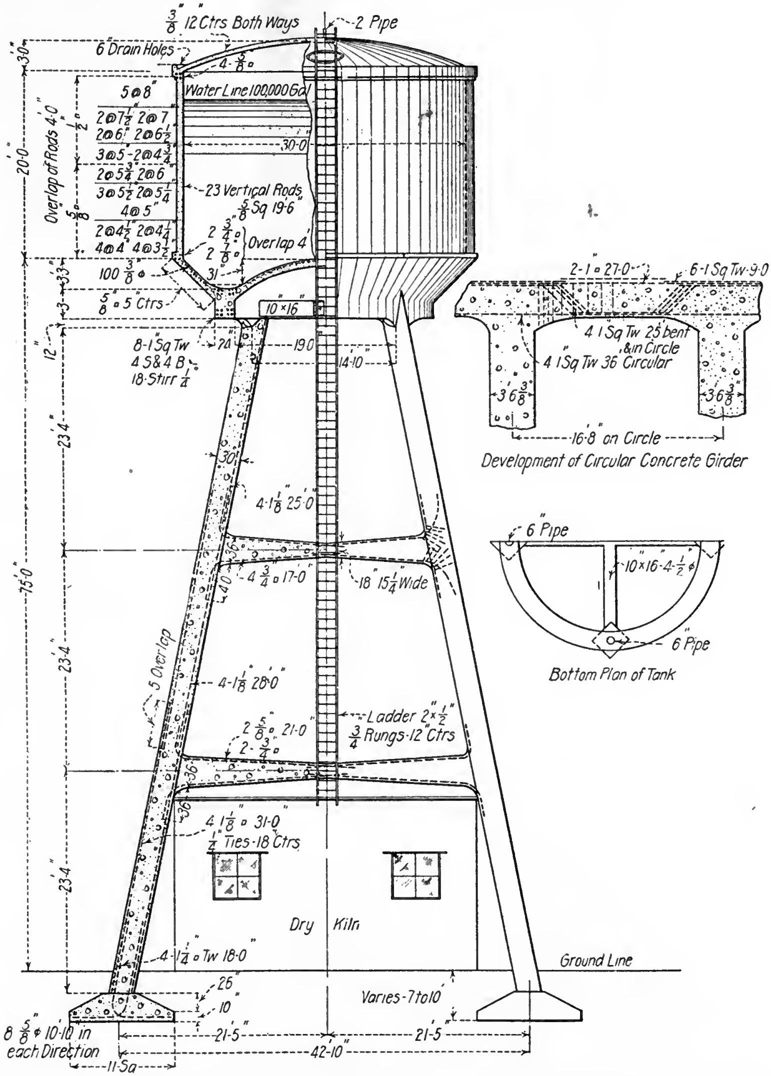


FIG. 148.—Water tank and tower of reinforced concrete. Chicago City Railway Co., Chicago, Ill.

house service, the old supply had become insufficient and it was decided to build an additional or larger tank, leaving the old

one and the pipe connecting it to the reservoir in their original condition. In providing a new tank, it was the intention to have a supply of 100,000 gallons of water above the level of the spouts which deliver water to the engines, which are about 12 ft. above the base of rail. It was further intended to have the new tank with the pipe supplying it, independent of the old one. Measurements of the flow of water from the reservoir on the hill showed a daily discharge of 190,000 gallons, which was sufficient for both old and new systems. An attempt to raise the level of the reservoir by banking it up with earth had pre-

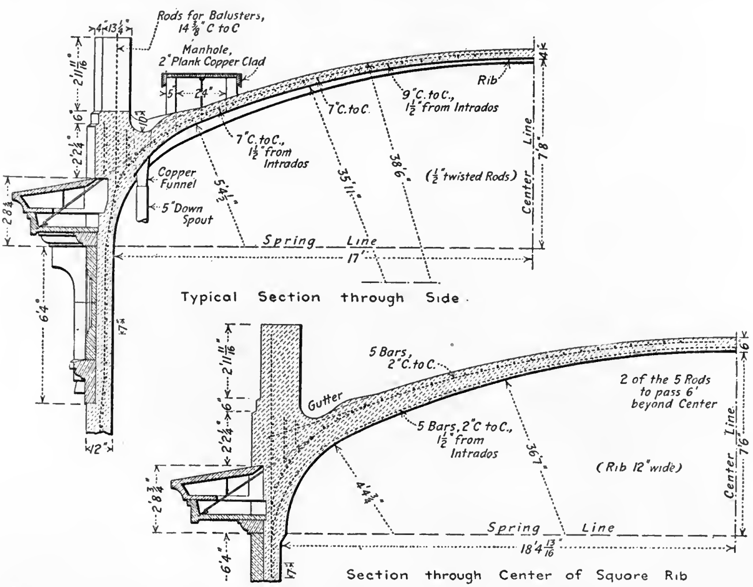


FIG. 149.—Dome of reinforced concrete water tower.

viously been made, but instead of rising as was expected the water seeped away and escaped. It appeared, therefore, that in order to secure a greater head of water it would be necessary to go farther up the valley and dam the water at a higher level, which plan was not favored on account of the extra expense.

Comparative designs and estimates were, therefore, made for several kinds of storage tanks, with a view to selecting the most economical and efficient one. The designs in all cases have steel tanks, and when towers are used they stand on concrete bases, with pedestals of sufficient size under the foot of each

column so the pressure on the soil will not exceed three tons per square foot. As the soil in this vicinity was sand and gravel it was excellent for foundations, and the assumed unit pressure comparatively small. Between the pedestals is a layer of concrete 12 in. thick over the whole remaining area, this feature being desirable, especially in winter, when water from leakage might soak below the foundations and cause injury from frost.

Where the tanks rest directly on the foundation without columns, the estimates provide for a solid base of concrete 4 ft. thick under the tanks, extending a foot outside of them at the upper surface, and stepped out still further at the bottom. In this case a large part of the cost is in the concrete, which is about four times greater than for designs with towers. Instead of using a solid block of concrete, the cost might be reduced by coring out the center part and filling it with sand. The earth would then be excavated to a depth of $3\frac{1}{2}$ ft. and a layer of concrete laid 12 in. thick, with a wall 2 ft. thick and 3 ft. high around the sides, the top of wall being 6 in. above the ground. After this concrete is set, the inside part is filled to a depth of 2 ft. with sand and gravel, well rammed in layers 6 in. thick. Over the filling is then placed another slab of concrete 12 in. thick, the top being covered with 1 in. of rich cement mortar. It should be 1 in. higher at the center than at the rim, and should have occasional water gutters about $1\frac{1}{2}$ in. deep formed in the concrete for drainage, radiating from the center to the circumference.

By comparing the designs it will be seen that the low, flat type of tank is not economical, and, generally, the more nearly equal are the diameter and height, the less will be the cost. Estimates in all cases include roofing the tank over with a wooden frame covered with $\frac{7}{8}$ in. sheathing and galvanized iron.

Comparative Designs. Style A.—This is a steel tank 10 ft. high and 48 ft. in diameter with a capacity of 100,000 gallons, standing on columns 12 ft. high (Fig. 150). Tank plates are $\frac{1}{4}$ in. thick, and vertical joints are lapped and double riveted, but the bottom has butt joints single riveted so the tank bottom will have even bearing on the beams or base. Joists are 7-in. I at 15 lb. per lineal foot, 2 ft. apart, resting on 15-in. I at 42 lb., spaced 9 ft. apart, the whole floor system being carried on 28 columns each made of four angles and a plate. Diagonal wind bracing is placed in two direc-

tions at right angles to each other. Inside of the tank are four light columns at the four corners of an 8-ft square, supporting the roof, and these stand on the bottom plate vertically over the columns under them. The supply pipe

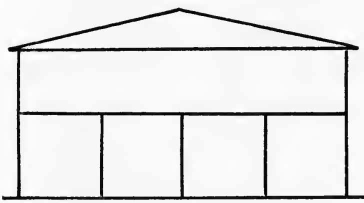


FIG. 150.

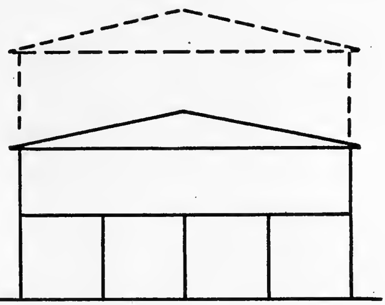


FIG. 151.

Tank designs.

enters the tank through the bottom near its center, and it has a gravity valve. When water in the tank is drawn off, the available or acting head is increased, and the velocity in the pipe is accelerated, but as the tank fills up the head is diminished and the velocity and discharge gradually decrease. The overflow pipe adjoins the inlet and both are enclosed in frost boxes made of matched lumber with double walls 6 in. apart, the space between them being filled with sawdust tightly rammed in place. The estimated cost of the complete structure, not including pipes or connections, is $5000.

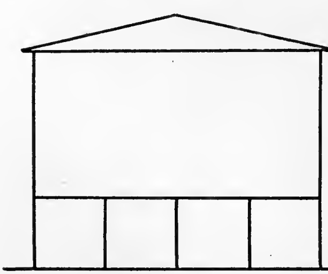


FIG 152.

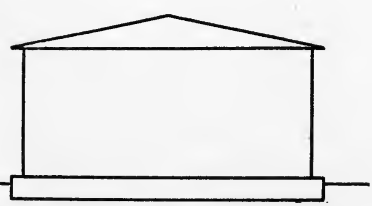


FIG. 153.

Tank designs.

Style B.—This is similar to A, and is heavy enough to support an additional height of 15 ft. (Fig. 151) if such extra capacity should be required in the future. The estimated cost of tank and tower complete in position is $6200.

Style C.—This is a modification of the last with the additional 15 ft. in height included (Fig. 152). The tank will have a capacity of 300,000 gallons. To fill a tank of this height, either a reservoir must be placed at a higher level from which it would be filled by gravity, or a small pumping plant installed. The cost of a pump with a sump and 1000 ft. additional pipe to connect the tank with the engine room where the pump would be placed is about $800. This amount added to the cost of the tank itself makes the total cost of both about $8300.

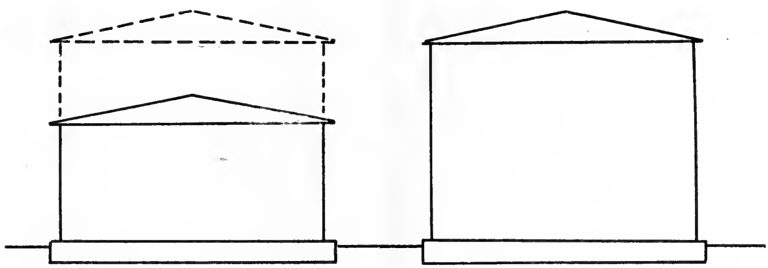


FIG. 154. FIG. 155.

Tank designs.

Style D.—It resembles Style A excepting that the tank stands directly on the concrete foundation (Fig. 153) instead of being elevated on columns. The amount of water stored in this tank above the level of the locomotive feed is no greater than for A, but the total amount is about 300,000 gallons, and the extra supply can be used to advantage in the watering of cars and for use around the engine house and machine shop. The cost including a solid concrete base 4 ft. thick is $6100.

Style E.—This is similar to the last, but is made sufficiently strong to support an additional 15 ft. in height in case it should be needed. The estimated cost is $7300 (Fig. 154).

Style F.—In this estimate, the 15 additional ft. in height referred to in the last is included, making the total capacity about 450,000 gallons. The estimated cost including the necessary pumping outfit is $9400 (Fig. 155).

Style G.—All the previous designs have had a diameter of

48 ft. but this one (Fig. 156) is reduced to 28 ft. and 28 ft. high of the required size to hold 100,000 gallons. It stands on columns 12 ft. high, and only one-third of its capacity, or about 30,000 gallons can be filled by gravity from the old reservoir. The remaining two-thirds must either be pumped or come from a reservoir at a higher level. In this case, as in C and F, the estimate includes an item of $800 for a pump and its equipment. If this pump should be out of order at any time, the tank will still contain 30,000 gallons of water, supplied from the old reservoir by gravity, which amount is equal to the whole capacity of the old wooden tank, and would temporarily be sufficient to meet the ordinary demand of locomotives. Without any reserve supply the estimated cost of this design, including the pumping outfit, is $4200.

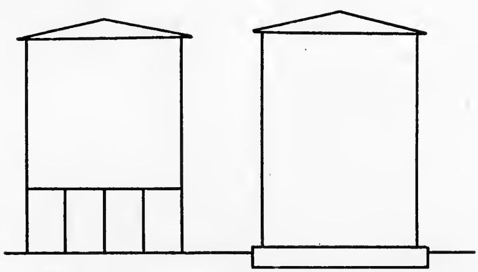


Fig. 156. Fig. 157.
Tank designs.

Style H.—This is similar to Style G, excepting that instead of supporting the tank on steel columns, it stands directly on a concrete base (Fig. 157), thereby increasing the storage capacity to 150,000 gallons. The estimated cost of the structure complete and in position, including the pump and accessories, is $4500. It is 28 ft. in diameter and 40 ft. high, and will always contain at least 30,000 gallons of water above the locomotive spouts, as this height will be maintained by gravity. The extra height of about 20 ft. can be filled by a centrifugal pump with 4-in. suction and delivery connections, which will be located in the machine shop convenient to the main driving shaft. The pump would cost $150 and is guaranteed to deliver 200,000 to 300,000 gallons per day, but with this capacity it need be in operation only during regular working hours or a portion of them. If it should ever become necessary to keep the pump

in constant operation, a small 8-h.p. engine might be installed at an additional cost of about $200.

The tank is supplied by an independent line of riveted steel pipe 10 in. in diameter, running from the old reservoir about one mile up the valley, and connecting to a cast-iron sump box or cistern under the machine shop floor. The sump has a movable top which can be taken off for cleaning or removing deposit that may have come down the supply pipe. It is permanently under the pressure of a 22-ft. head of water, and from it a centrifugal pump forces water into the storage tank. Valves are provided on each side of the sump to shut off the flow of water in the pipes. The supply enters the tank from the bottom, so it will be filled up to the 20½-ft. level by gravity before pumping is needed. By connecting the supply pipe to the bottom the greatest velocity is secured, and when water in the tank is low it fills again at a greater speed than when tank and reservoir are approaching the same level. No frost boxes or other pipe protection are required, as the pipes are embedded in the concrete below the level of the ground. The estimated cost of $4500 includes a solid block of concrete 4 ft. thick, but this cost may be reduced by coring out the central part as previously described, and filling it with solid sand and gravel. The valve over the supply pipe in the bottom opens upward so that water may always enter and it is kept closed by gravity and by the weight of water above it. A 10-in. supply pipe under a head of only 2 ft. will deliver water at the rate of 2.9 cu. ft. or 21 gallons per second, which is more than sufficient to keep the tank continuously and adequately supplied. It is covered over with a conical roof, framed with wood and covered with galvanized iron.

Selection of Style.—The considerations in selecting a design from the several possible ones are that it should contain enough water to supply eight to ten locomotives daily in both directions, or a total of sixteen to twenty, the average capacity of their tanks being 40,000 gallons. There must also be enough water to replenish car tanks on the passenger trains. The round house will require water for cleaning, and the machine shop and boiler room attached thereto will need from 15,000 to 20,000 gallons per day for the boilers and general service. The hotels and other houses must also be supplied, and adjoining the railroad depot is a fire plug which may at any time be brought into active service.

Choice must also be made between gravity supply and pumping. A gravity system is usually preferred, because it requires no attention and there is no machinery to break down or become disordered. Of the four designs considered, in which water supply must come from a higher reservoir or be forced up with pumps, the natural supply is greatly preferred and a higher basin may be built at any time in the future and pipe connection made thereto. A suitable site for such a water basin could be found 2 or 3 miles farther up the valley at a place where the hills converge, where the head would have an additional height of 200 ft. The cost of this reservoir and the 2 or 3 miles of pipe would be from $4000 to $5000, while the pumping plant can be installed for an additional cost of only $800. The reason for the low cost of a pumping plant is, that the machine shop adjoining the round house which is only 500 ft. from the proposed water tank, is already equipped with power, and the only additional machinery needed is a pump which may be run by belt from the overhead shafting.

The third consideration in choosing from the possible types described above is the matter of cost, a summary of which is given in the following schedule:

	Cost	Capacity in gallons
Style A	$5000	100,000
Style B	6200	100,000
Style C	8300	300,000
Style D	6100	300,000
Style E	7300	300,000
Style F	9400	450,000
Style G	4200	100,000
Style H	4500	150,000

In selecting a tank from the eight designs considered, Style H, for a tank 40 ft. in height and 28 ft. in diameter, standing on a solid concrete base, offered the greatest advantages and was therefore chosen. Its comparative merits have previously been given.

Other designs for water tanks or stand pipes are shown in Figs. 158, 159 and 160.

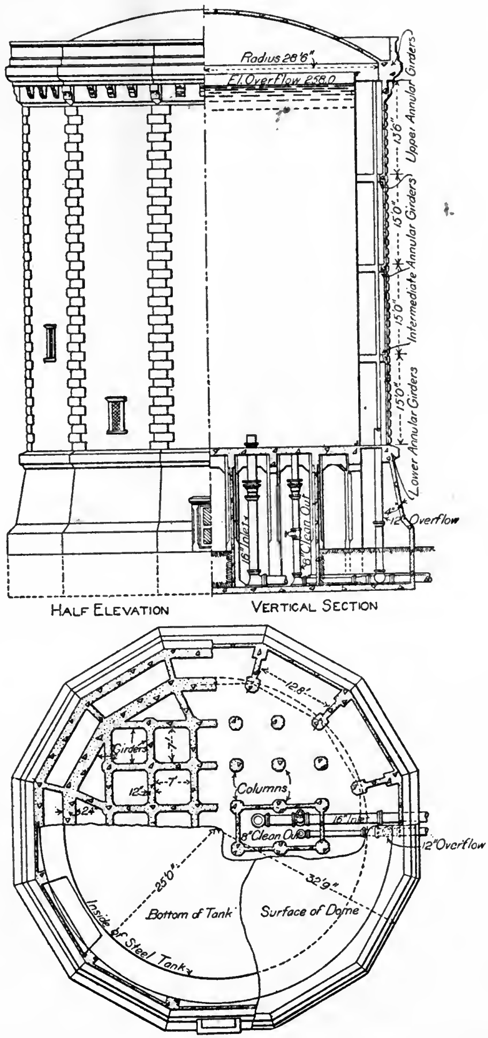


Fig. 158.—Steel and concrete water tank at Grand Rapids, Michigan. Capacity 885,000 gallons.

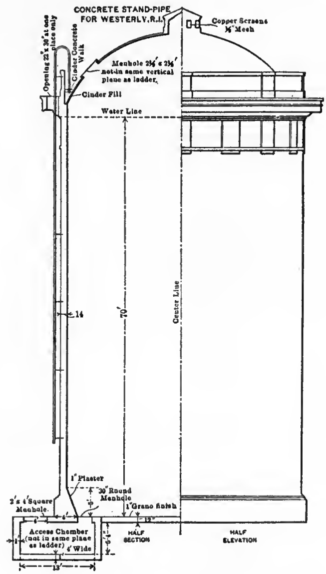


FIG. 159.—Reinforced concrete stand pipe, Westerly, R. I.

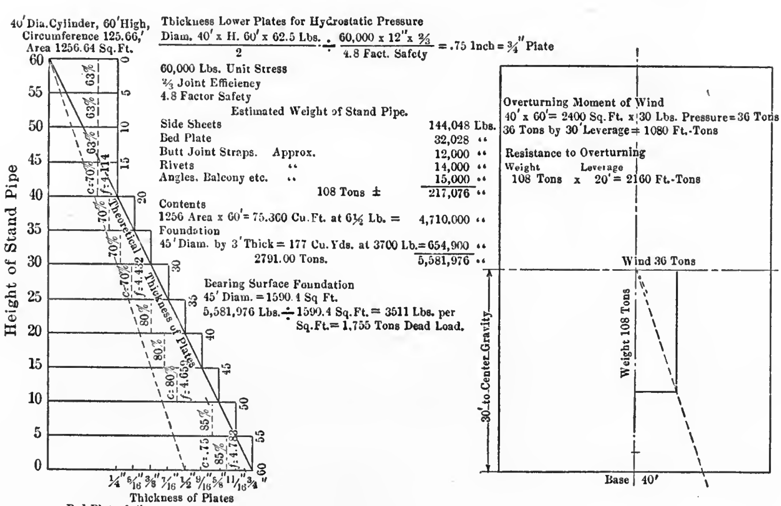


FIG. 160.—Stand pipe stress sheet.

TABLE XXIV.—STANDARD DIMENSIONS FOR ROUND BOTTOM STEEL TANKS

Capacity in gallons	Outside diameter in feet	Height of tank side not including curved bottom	
		Ft.	In.
10,000	11	10	0
15,000	12	14	0
20,000	13	16	0
25,000	14	17	0
30,000	15	18	0
35,000	16	18	0
40,000	17	18	0
45,000	17	21	0
50,000	18	20	4
55,000	18	23	0
60,000	19	22	0
65,000	19	24	4
70,000	20	23	0
75,000	20	25	3
80,000	21	24	0
90,000	21	27	9
100,000	22	28	0
125,000	24	29	0
150,000	25	32	6
175,000	26	35	5
200,000	28	34	1
250,000	30	37	4
300,000	32	39	3

TABLE XXV.—CAPACITY OF CYLINDRICAL TANKS, INCLUDING HEMISPHERICAL BOTTOM

Diameter in feet	Capacity in gallons per vertical foot	Capacity in gallons of hemispherical bottom
5	146.9	244.8
6	211.5	423.0
7	287.9	671.8
8	376.0	1002.7
9	475.9	1427.1
10	587.6	1958.3
11	710.9	2606.6
12	846.0	3384.6
13	992.9	4302.6
14	1151.5	5373.7
15	1321.9	6609.5
16	1504.1	8021.9
17	1697.9	9621.4
18	1903.6	11421.6
19	2120.9	13432.4
20	2350.1	15667.3
21	2591.0	18137.0
22	2843.6	20853.1
23	3108.0	23828.0
24	3384.1	27072.8
25	3672.0	30600.0
26	3971.6	34420.5
27	4283.0	38547.0
28	4606.2	42991.2
29	4941.0	47763.0
30	5287.7	52877.0

TABLE XXVI.—SHOWING CAPACITY OF PUMPS OF GIVEN DIAMETER AND LENGTH OF STROKE

Diameter of cylinder, inches	Length of stroke in inches, and capacity per stroke in gallons, of pump cylinder with given diameter										
	6	8	9	10	12	14	15	16	18	20	24
1¾	.0625	.0833	.0937	.1041	.1249	.1457	.1562	.1666	.1874	.2082	.2499
2¾	.1543	.2057	.2313	.2571	.3085	.3598	.3855	.4114	.4626	.5142	.617
3¼	.2154	.2872	.3231	.3594	.4312	.503	.5385	.5748	.666	.7182	.8624
4	.3264	.4352	.4896	.544	.6528	.7616	.816	.8704	.9792	1.088	1.3056
4¼	.3684	.4912	.5526	.6141	.7368	.8596	.921	.9824	1.105	1.228	1.473
4½	.4131	.5508	.6196	.6885	.8262	.9639	1.0327	1.1016	1.2393	1.377	1.6524
4¾	.4602	.6136	.6903	.7671	.9204	1.073	1.15	1.2227	1.380	1.534	1.84
5	.51	.68	.765	.85	1.02	1.19	1.275	1.36	1.53	1.7	2.04
5¼	.5622	.7496	.8433	.9371	1.124	1.311	1.405	1.499	1.686	1.874	2.228
5½	.6171	.8228	.9256	1.0285	1.2342	1.4399	1.5427	1.6456	1.8513	2.057	2.4684
5¾	.6744	.8992	1.011	1.124	1.318	1.573	1.686	1.789	2.022	2.248	2.696
6	.7344	.9792	1.1016	1.2240	1.4688	1.7136	1.8362	1.9584	2.2032	2.448	2.9376
6¼	.7968	1.062	1.195	1.328	1.593	1.859	1.992	2.124	2.39	2.656	3.186
6½	.8610	1.1488	1.2926	1.4364	1.7955	2.0109	2.1546	2.2982	2.5885	2.8728	3.4473
6¾	.9294	1.239	1.394	1.549	1.858	2.168	2.323	2.479	2.788	3.098	3.716
7	.9996	1.3328	1.4994	1.666	1.9992	2.3324	2.499	2.6656	2.9988	3.332	3.9984
7¾	1.225	1.633	1.837	2.042	2.45	2.858	3.063	3.266	3.674	4.084	4.9
8	1.3056	1.7408	1.9584	2.176	2.6112	3.0464	3.264	3.4816	3.9168	4.352	5.2224
9	1.6524	2.2032	2.4786	2.754	3.3048	3.8556	4.131	4.4064	5.0572	5.508	6.6096
10	2.04	2.72	3.06	3.4	4.08	4.76	5.1	5.44	6.12	6.8	8.16
11	2.464	3.2911	3.7258	4.1139	4.9367	5.7595	6.1709	6.5823	7.4051	8.2279	9.8735
12	2.9376	3.9168	4.4064	4.896	5.8752	6.8544	7.344	7.833	8.8128	9.792	11.7504
13	3.445	4.596	5.170	5.745	6.894	8.042	8.616	9.192	10.34	11.49	13.78

TABLE XXVII.—THEORETICAL HORSE-POWER REQUIRED TO RAISE WATER TO DIFFERENT HEIGHTS

Gallons per minute	Feet												
	10	25	50	75	100	125	150	175	200	250	300	350	400
5	.012	.031	.06	.09	.12	.16	.19	.22	.25	.31	.37	.44	.50
10	.025	.062	.12	.19	.25	.31	.37	.44	.50	.62	.75	.87	1.00
15	.037	.094	.19	.28	.37	.47	.56	.66	.75	.94	1.12	1.31	1.50
20	.050	.125	.25	.37	.50	.62	.75	.87	1.00	1.25	1.50	1.75	2.00
25	.062	.156	.31	.47	.62	.78	.94	1.09	1.25	1.56	1.87	2.19	2.50
30	.075	.187	.37	.56	.75	.94	1.12	1.31	1.50	1.87	2.25	2.62	3.00
35	.087	.219	.44	.66	.87	1.08	1.31	1.53	1.75	2.19	2.62	3.06	3.50
40	.100	.250	.50	.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00
45	.112	.281	.56	.84	1.12	1.41	1.69	1.97	2.25	2.81	3.37	3.94	4.50
50	.125	.312	.62	.94	1.25	1.56	1.87	2.19	2.50	3.12	3.75	4.37	5.00
60	.150	.375	.75	1.12	1.50	1.87	2.25	2.62	3.00	3.75	4.50	5.25	6.00
75	.187	.469	.94	1.40	1.87	2.34	2.81	3.28	3.75	4.69	5.62	6.56	7.50
90	.225	.562	1.12	1.68	2.25	2.81	3.37	3.94	4.50	5.62	6.75	7.87	9.00
100	.250	.625	1.25	1.87	2.50	3.12	3.75	4.37	5.00	6.25	7.50	8.75	10.00
125	.312	.781	1.56	2.34	3.12	3.91	4.69	5.47	6.25	7.81	9.37	10.94	12.50
150	.375	.937	1.87	2.81	3.75	4.69	5.62	6.56	7.50	9.37	11.25	13.12	15.00
175	.437	1.093	2.19	3.28	4.37	5.47	6.56	7.66	8.75	10.94	13.12	15.13	17.50
200	.500	1.250	2.50	3.75	5.00	6.25	7.50	8.75	10.00	12.50	15.00	17.50	20.00
250	.625	1.562	3.12	4.69	6.25	7.81	9.37	10.94	12.50	15.72	18.75	21.87	25.00
300	.750	1.875	3.75	5.62	7.50	9.37	11.25	13.12	15.00	18.75	22.50	26.25	30.00
350	.875	2.187	4.37	6.56	8.75	10.94	13.12	15.31	17.50	21.87	26.25	30.62	35.00
400	1.000	2.500	5.00	7.50	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00
500	1.250	3.125	6.25	9.37	12.50	15.62	18.75	21.87	25.00	31.25	37.50	43.75	50.00

TABLE XXVIII.—FIRE STREAMS

	$\frac{3}{4}$-in. smooth nozzle					$\frac{7}{8}$-in. smooth nozzle					1-in. smooth nozzle				
Pounds pressure, nozzle	20	30	40	50	60	20	30	40	50	60	20	30	40	50	60
Pounds pressure lost in each 100 ft. $2\frac{1}{2}$-in. hose.	1.4	2.1	2.9	3.6	4.2	2.6	4.0	5.2	6.5	8.0	4.7	6.7	9.0	11.3	12.7
Vertical height of stream	38	53	72	81	91	38	56	73	85	94	39	57	74	87	97
Horizontal distance of stream	50	68	77	89	99	55	75	91	97	108	58	73	97	106	115
Gallons discharged per minute	68	82	95	106	116	92	113	130	145	160	125	147	170	190	209

TABLE XXIX.—FRICTION OF WATER IN PIPES

Friction loss in pounds pressure per square inch for each 100 ft. of length in different sizes clean iron pipe discharging given quantities of water per minute.

Gallons per minute	Size of pipe inside diameter														
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.
5	3.3	0.84	0.31	0.12	....	....	....	....	....	....	....	....	....	....	....
10	13.0	3.16	1.05	0.47	0.12	....	....	....	....	....	....	....	....	....	....
15	28.7	6.98	2.38	0.97	....	....	....	....	....	....	....	....	....	....	....
20	50.4	12.3	4.07	1.66	0.42	....	....	....	....	....	....	....	....	....	....
25	78.0	19.0	6.40	2.62	....	0.21	0.10	....	....	....	....	....	....	....	....
30	....	27.5	9.15	3.75	0.91	....	....	....	....	....	....	....	....	....	....
35	....	37.0	12.4	5.05	....	....	....	....	....	....	....	....	....	....	....
40	....	48.0	16.1	6.52	1.60	....	....	....	....	....	....	....	....	....	....
45	....	....	20.2	8.15	....	....	....	....	....	....	....	....	....	....	....
50	....	....	21.9	10.0	2.44	0.81	0.35	0.09	....	....	....	....	....	....	....
75	....	....	26.1	22.4	5.32	1.80	0.74	....	....	....	....	....	....	....	....
100	....	....	....	39.4	9.46	3.20	1.31	0.33	0.05	....	....	....	....	....	....
125	....	....	....	....	14.9	4.89	1.99	....	....	....	....	....	....	....	....
150	....	....	....	....	21.2	7.00	2.85	0.69	0.10	....	....	....	....	....	....
175	....	....	....	....	28.1	9.46	3.85	....	....	....	....	....	....	....	....
200	....	....	....	....	37.51	12.47	5.02	1.22	0.17	....	....	....	....	....	....
250	....	....	....	....	....	19.66	7.76	1.89	0.26	0.07	0.03	0.01	....	....	....
300	....	....	....	....	....	28.06	11.2	2.66	0.37	0.09	0.04	....	....	....	....
350	....	....	....	....	....	....	15.2	3.65	0.50	0.12	0.05	0.02	....	....	....
400	....	....	....	....	....	....	19.5	4.73	0.65	0.16	0.06	....	....	....	....
450	....	....	....	....	....	....	25.0	6.01	0.81	0.20	0.07	0.03	....	....	....
500	....	....	....	....	....	....	30.8	7.43	0.96	0.25	0.09	0.04	0.017	0.009	0.005
750	....	....	....	....	....	....	....	....	2.21	0.53	0.18	0.08	....	....	....
1,000	....	....	....	....	....	....	....	....	3.88	0.94	0.32	0.13	0.062	0.036	0.020
1,250	....	....	....	....	....	....	....	....	....	1.46	0.49	0.20	....	....	....
1,500	....	....	....	....	....	....	....	....	....	2.09	0.70	0.29	0.135	0.071	0.040
1,750	....	....	....	....	....	....	....	....	....	....	0.95	0.38	....	....	....
2,000	....	....	....	....	....	....	....	....	....	....	1.23	0.49	0.234	0.123	0.071
2,250	....	....	....	....	....	....	....	....	....	....	....	0.63	....	....	....
2,500	....	....	....	....	....	....	....	....	....	....	....	0.77	0.362	0.188	0.107
3,000	....	....	....	....	....	....	....	....	....	....	....	1.11	0.515	0.267	0.150

CHAPTER XXV

STEEL CHIMNEYS

This type of stack is used chiefly for lofty ones with heights of 150 to 300 ft. They have the advantage of occupying small space, and costing 30 to 50 per cent. less than brick. The effect of wind on cylindrical surfaces is only half as great as on flat ones of the same width, and in metal stacks, the overturning tendency may be resisted by increasing the bottom diameter. This obviates the use of unsightly guy ropes, which at once betray their weakness. They should be proportioned for a wind pressure of 50 lb. per square foot, corresponding to a velocity of 100 miles per hour. The small weight of steel draft stacks produces a corresponding saving in the cost of the foundations. One 300 ft. in height would have a bottom wall thickness of 55 to 60 in. in brick, and 18 to 24 in. in reinforced concrete, requiring greater width and sustaining power in the foundation. Metal stacks can be erected much more rapidly than masonry, and an ordinary one 100 ft. in height should easily be completed within thirty days. They have, however, the disadvantage of requiring frequent painting, at least once every four years (Fig. 161).

Their required height depends somewhat on the surroundings, and the elevation of adjoining hills and buildings, and they are more effective on high ground than in a valley. But their height should always be at least twenty times their inside diameter.

The need of lining will depend largely on the proximity of the boilers, because when removed from the source of heat the smoke and gases will have cooled enough before reaching the stack to make lining unnecessary. Some builders make a practice of lining all stacks exceeding 75 ft. in height, and reinforced concrete is now being much used for this purpose.

With the relative proportion of diameter and height as given above, the thickness of plates should be according to the following table:

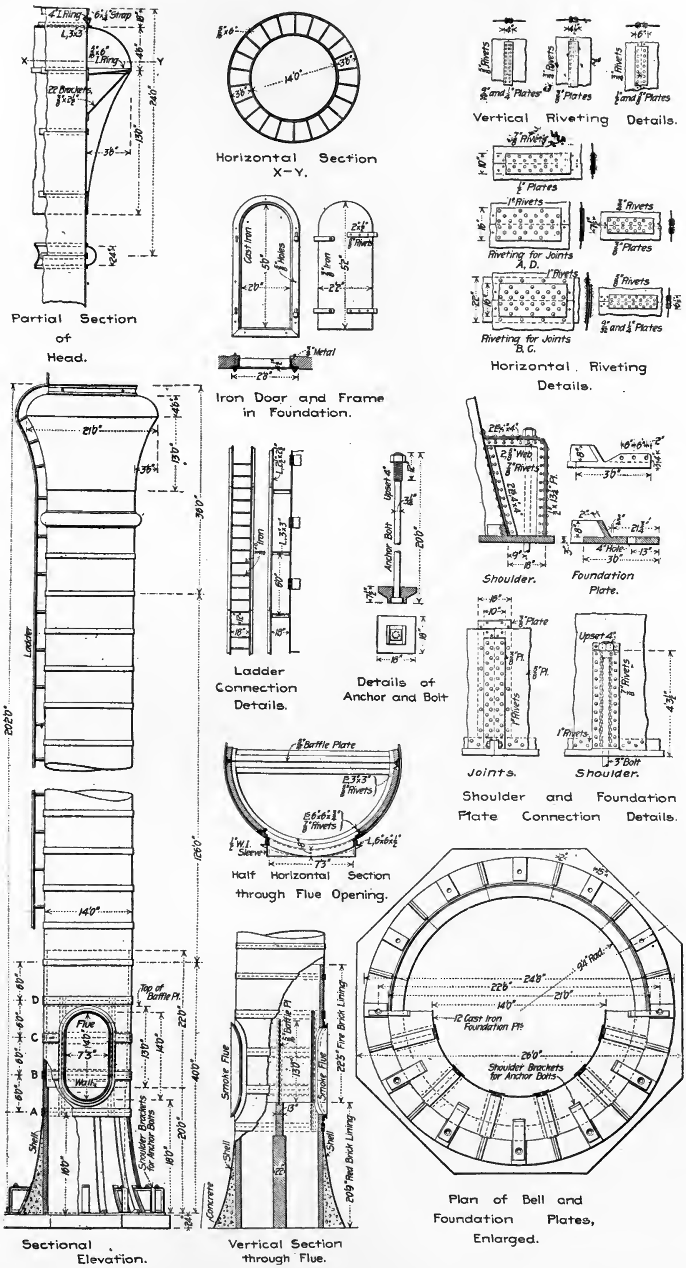


Fig. 161.—Steel chimney for the St. Louis Transit Co. Height 202 ft.

Upper	40 ft.	of stack should have plates	3/16 in. thick.
	40 to 60	ft. below the top, plates	1/4 in. thick.
	60 to 80	ft. below the top, plates	5/16 in. thick.
	80 to 100	ft. below the top, plates	3/8 in. thick.
	100 to 120	ft. below the top, plates	1/2 in. thick.

The width of base should usually be increased to twice the upper diameter, the change starting at a height of five diameters above the foundation (Fig. 162). Up to 200 ft. in height, the average cost should not exceed $10 to $15 per vertical foot.

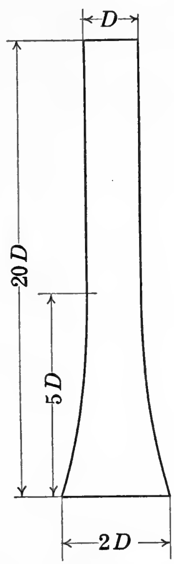


FIG. 162.—Chimney diagram.

A ladder should be placed on the outside for use when painting, and a circular trolley track near the top, standing out a few inches from the cylinder, will permit workmen on a suspended platform to move themselves about to any desired position. The whole appearance is improved by the addition of a neat ornamental iron top with projecting cornice.

A cheaper type of metal stack may be made in rectangular form, framed with structural shapes, and lined inside with corrugated iron. Angles are convenient for corner members, and channels for the horizontal girths, which should be placed about 9½ ft. apart vertically, for 10-ft. metal sheets. They must usually be guyed at intervals of about 30 ft. apart vertically. One of this form, 190 ft. in height, and 10 by 12 ft. in sectional area, erected at Garfield, Utah, weighed 55,000 lb. and cost less than $4900, equivalent to 8.8 cents per pound.

CHAPTER XXVI

FIRE PROTECTION

The need of adequate fire protection can best be shown by reference to statistics. During the year 1907, which was free from any great conflagrations such as those which visited the cities of Chicago, Baltimore and San Francisco, the fire loss in the United States was as follows:

Property	$215,000,000
Lives lost	1450
Persons injured	5650

About two-thirds of the above loss was from wooden buildings. Reports from the insurance companies show that there are annually about 2000 fires in manufacturing buildings in the United States, resulting in losses of $25,000 or more, each, making a yearly loss equal to $2.50 for every living person in the country. At least one quarter of these fires include more than one building. Reports from seven large cities of Europe reveal a much smaller loss, the average being only 30 cents for each inhabitant.

Fire loss is relatively small in plants which are built and equipped according to the standard regulations of the fire insurance companies, the average for ten years being only 4 cents per $100 of value, while in plants devoid of such protection the loss is about 60 cents per $100. While fires cannot be entirely avoided, it is now well known that by taking the proper precaution, at least 60 per cent. of them would never occur. Insurance is merely a means of ready relief to the first loser, but when viewed in a wider light it only distributes loss among a greater number of persons, the total to the community remaining the same.

Methods of Protection.—Fire protection is secured in several ways, some of which are

1. Use of fireproof building material.
2. Separation of stories and departments.
3. Installation of fire-fighting appliances.
4. Frequent inspection.
5. Fire drill.

Fireproof Materials.—The best way to prevent fire is to make the building as nearly fireproof as possible. Timber should be in large sizes, and framed according to the standards of "Slow Burning or Wood Mill Construction" which is described elsewhere. When in large sizes, timber is decomposed very slowly in a fire, and it has been found much safer than unprotected steel. In comparing Slow Burning Construction with the older type having small joist 16 to 18 in. apart, as in residences, a floor with heavy framing will last five to ten times as long in a fire as one with joist. Comparative tests of two buildings under similar conditions showed that the heavy framing stood for twenty minutes in the same fire that caused joists to collapse in less than three minutes. Wooden walls may be 25 per cent. cheaper than brick and require less expensive foundations, but when used, small pieces that will easily burn, should be avoided.

Unprotected steel must not be used, but must be covered with fireproof material such as brick, terra-cotta or concrete, though a better way is to make the whole building of concrete. Stone is not reliable in fire, for it splits and cracks and is quite inferior to brick or concrete.

Roofs should be as nearly fireproof as possible, especially over fires, or adjoining stacks or flues. If the uncovered hand cannot be held against a hot pipe it is not safe to be in contact with wood, for when framing becomes thoroughly dry it is in greater danger of taking fire. Chimneys where they pass through the roof should be surrounded by a metal hood. A flue is not always hottest near the furnace, for some of the gases may not fully ignite until reaching the open air. Pipes are, therefore, often hotter near the top than adjoining the furnace. If a pipe should endanger the roof, the danger may sometimes be lessened by lengthening it.

Small framing members such as are frequently found in skylights, ventilators, gutters, and louvres, should be avoided, as they easily catch and hold fire, and the roof exterior should be well covered with some such covering as gravel or sheet metal.

Arrangement of Departments.—Departments where the fire risk is greatest should be divided from the rest by fire walls, or placed in separate buildings, and, as far as possible, floors and departments should be separated from each other. Openings through the floors must be avoided, for they not only allow fire to pass up through the building, but heat from fire in a lower

story may rise through floor openings and cause sprinklers in upper stories to open with accompanying water loss, even where fire may have done no injury. Stairs between the floors should be in separate towers outside the building rectangle, with access to them through automatic closing doors. When openings through the floors are unavoidable, they should be covered with self-closing hatches.

Protective Systems.—Automatic sprinkling systems are by far the best fire extinguishers, for not less than 70 per cent. of all fires in buildings so equipped, have been put out. Sprinklers are of two kinds, usually known as (1) the wet system, and (2) the dry system. The first can be used only where pipes will not freeze, while the second is suitable anywhere. Small water pipes are suspended below the ceilings, with sprinkler nozzles 6 to 10 ft. apart, the nozzles being sealed with soft metal which melts easily at a temperature of about 150 degrees, or about 50 degrees above the highest summer heat. These pipes are connected to at least two independent sources of water supply, usually the public system of the city and a private elevated tank or stand pipe. Ceiling pipes vary in size from ¾-in. diameter for that which supplies a single head, to 6-in. diameter for those supplying 200 heads. Nozzles (Fig. 163) are made in several ways and should stand above the pipe in order to throw water on the ceiling from which it is deflected to the floor. This not only gives the greatest spread of water but permits the pipes to be drained, all those on the ceiling having a slight inclination toward the vertical ones. Pipes must not be enclosed in the ceiling or in casing, but must be open for inspection.

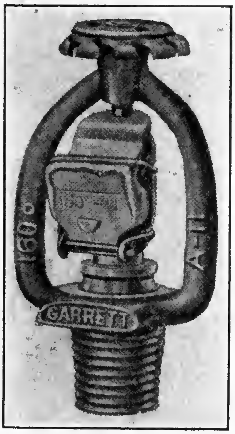


FIG. 163.—Sprinkler nozzel.

In the "dry system" where water in the pipes would freeze, water is held back by compressed air, but is liberated when the sprinkler fuses melt.

In the outside system of yard pipes for the sprinklers the supply to each building should be regulated by a valve outside the building which can be closed in case any one building is

destroyed, for if such pipes were left open, the pressure in the other buildings would be lowered.

Sprinkler systems, including the whole equipment, cost 6 to 10 cents per square foot of floor area. In some cases the inside

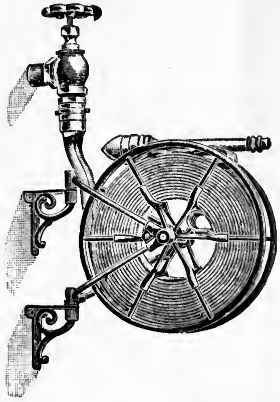


Fig. 164.

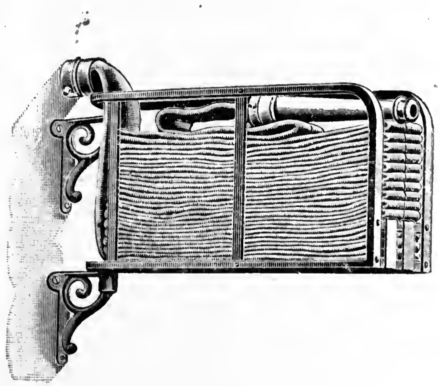


Fig. 165.

Hose coils.

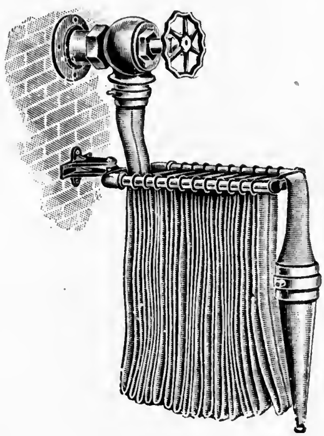


Fig. 166.

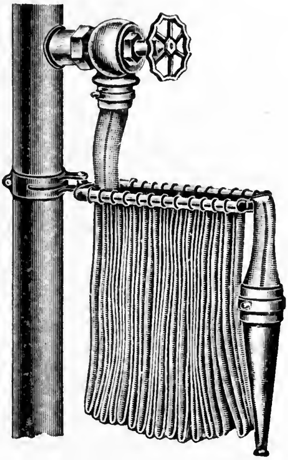


Fig. 167.

Hose coils.

work alone, with piping and heads, has cost 7 cents per square foot, and 10 cents per foot including the cost of tanks, yard pipes, etc.

Other fire fighting appliances include sand pails, water buckets, hose coils (Figs. 164–167) and chemical extinguishers (Fig. 168).

These are useful chiefly for putting out fire in its first stage before the sprinklers have begun to work. Hose pressures should not exceed 40 to 60 lb. per square inch, for those who are not accustomed to handling hose are unable to control the nozzle at high pressures. The discharge of water through nozzles of different size at a pressure of 100 lb. per square inch is as follows:

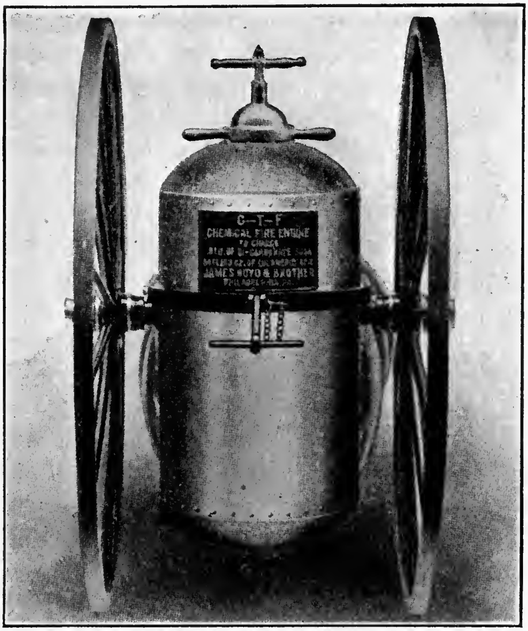


FIG. 168.—Chemical extinguisher.

1 ¼ in. nozzle, discharges at 100 lb., 466 gallons per minute.
1 ½ in. nozzle, discharges at 100 lb., 671 gallons per minute.
1 ¾ in. nozzle, discharges at 100 lb., 904 gallons per minute.
2 in. nozzle, discharges at 100 lb., 1194 gallons per minute.

Inspection.—Rigid and frequent inspection of plants by officers of the Fire Insurance Companies is one of the best methods of preventing fire loss. These inspections are made every three months by different men who are not supplied with previous reports, and independent inspections of this kind are therefore a check on each other. Examination is made of every thing pertaining to fire risk, including the methods of lighting, heating,

type of construction, building contents and appliances, nearness of fire hydrants and the local protective system. The degree of order and cleanliness maintained inside the building, and the familiarity of the occupants with the methods provided for fire extinction, are all noted and reported. Such inspections are, of course, quite expensive, but have proved to be ultimate economy.

While inspection by officers of the insurance companies is valuable, it should not be left wholly to them, because their examinations are frequently more for their own benefit than for the owners or occupants. The insurance company may be willing to receive a higher rate, and are often most interested in seeing that the rate is high enough.

Cleanliness and Order.—Prevention of fire is better than extinction, for loss is rarely covered by the insurance. Failure to complete contracts on time, the scattering of workmen and loss of business, are matters not in the insurance policies. It is therefore wisdom to use every effort toward the prevention of fire, and no measures are more effective in this direction than order and cleanliness. Certain rules should be established in reference to smoking or the use of fire about the buildings, and violations of these rules should be punished by suspension or dismissal.

Buildings should be cleaned daily during daylight, preferably just before closing. This will not only avoid the need of artificial light and its accompanying danger, but will give janitors better light for their work, and avoid any excuse for improper service. Aisles will no doubt be kept clean, and attention should be given to space under tables, behind machines, in closets, or under stairs, where dirt is most likely to accumulate. Rubbish must not be allowed to collect, but must be removed from the shops to outer sheds or to the dump. Rubbish boxes should be of metal with self-closing covers, and they should be emptied daily.

Dust is a common cause of fire, and once or twice a month, the whole building interior should be swept and dust removed from such places as door and window heads, and from the truss framing if it is exposed. Certain articles used about shops often cause spontaneous combustion. Dust, shop sweepings, or waste when soaked with oil frequently take fire, and sal ammoniac and iron filings mixed with dirt are also dangerous, and these should not be permitted to collect or remain unprotected. Likewise

the dust from grinding stones and emery wheels settling on wet surfaces is likely to take fire. Cellars, attics and all hidden places should be kept clean and clear of rubbish, and the prevention of fire should be included as part of the regular expense.

Employees in pattern and templet shops have occasionally been found drying lumber over furnaces, or using other dangerous means to hasten the seasoning, and at other times, torches and gasoline lamps have been carelessly used. Any such careless conduct should be effectively stopped and its repetition prevented.

Fire Drill.—A regular system of fire drill should be maintained at every factory. These systems should be governed by law and should be uniform for all plants, so that employees changing from one place to another will not be obliged to learn a new lot of regulations, or be confused with orders with which they are not familiar. The system of drill should be military in character, under the direction of officers of different rank. It should be directed by a fire marshall whose authority in these matters is supreme, and captains should have charge of floors or buildings, with lieutenants for separate rooms. The organization should be extended further if necessary, with foremen to direct the movements of occupants in companies of twenty-five to fifty persons. All officers should be accustomed to command, so their authority in fire emergencies will be respected. Other men will be assigned to special duties as required, and to prevent crowding, stairs and fire escapes should have a guard at every landing. The officers should make daily or frequent inspections, noting stairs, exits and passage ways to see that they are always clear. Doors must always open outward and must be examined to see that those at exits which are seldom used excepting at fire drill, are accessible. Gongs or other signals must be kept in order.

Fig. 169.—Hand extinguisher.

Full printed instructions for fire drill and protection must be posted conspicuously throughout the buildings, and in different

languages, if necessary. Orders should be announced by bells or gongs in the different stories under the direction of the captains, who receive their orders from the marshall on an outer gong of different tone. Fire is first announced by a succession of strokes on the marshall's gong, and immediately all occupants of the building should come to attention, shut off power from their machines, and stop work. Successive orders from the floor captains may be given as follows:

One stroke of gong, meaning to clear the passage ways.
Two strokes of gong, meaning to form in line.
Three strokes of gong, meaning to march out of the building.

These drills should be given at least once a fortnight at irregular intervals without previous announcement, and all occupants of the building must take part. The regular entrances with which employees are most familiar should, as far as possible, be used in preference to any others. If there are insufficient exits or dangerous defects in the protective system, they will be disclosed by these drills and may then be remedied.

All exits must be indicated by red lights. Fire officers should keep with them a pocket memoranda with the names of all occupants of their respective rooms or departments, and after each drill, names should be announced and checked off on the list, to see that all are accounted for. Before marching from the building, all lights should be extinguished.

In case of fire, hand extinguishers (Fig. 169) should be used to the limit of their usefulness before resorting to other methods. When passing through dense smoke, a wet handkerchief, cloth, or waste, should be tied over the mouth and nose, and as smoke rises and has the least density at its lowest level, escape in extreme cases may be made by crawling along the floor.

CHAPTER XXVII

CRANES

Hand Traveling Shop Crane.—The accompanying illustration (Fig. 170) shows a typical shop crane, designed by the writer, in a series of dimensions and capacities, several of which have been built and put into successful operation. The principal

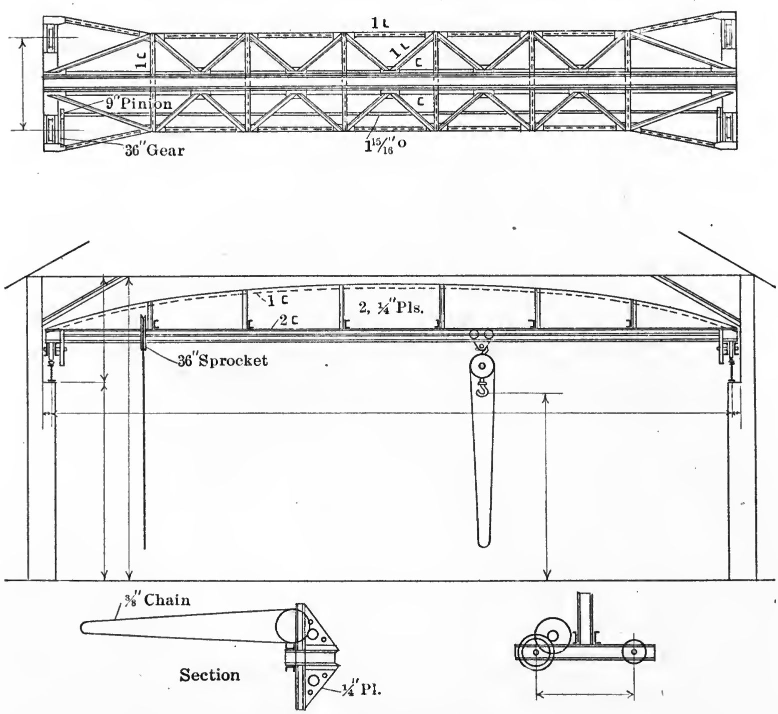


Fig. 170.—Shop crane.

feature of the design is, that it gives the greatest amount of lift or clearance beneath the bridge, and leaves space for knee braces in the building frame. In steel frame buildings with traveling cranes of the usual type, vertical space is lost by keeping the crane low enough to clear the knee braces. If such clearance is

not provided, and knee braces are omitted or made so small that they are almost useless, the stiffness of the whole frame is sacrificed. In this design, however, ample room is left for deep braces, and the crane bridge is placed close up under the roof trusses, resulting in a stiff building frame and maximum clearance under the crane.

Another important feature of the design is the side or lateral bracing. It is important that a shop crane should travel truly parallel with the building. But with insufficient bracing the frame of the crane is liable to get out of square, causing one end to travel slightly in advance of the other. To prevent such action this crane has wide side bracing connecting out to the extremities of the end trucks.

As previously stated, these cranes are made of various sizes and capacities, but the standard form of specification is as follows:

SPECIFICATION FOR HAND TRAVELING CRANE.

General.—The crane will be as shown on the print accompanying these specifications. It consists of a box girder grooved on the upper side, and mounted at the ends on a pair of trucks which are carried on 24-in. cast-iron chilled tread wheels. The wheels are ground to run on standard . . . . . lb. track rails.

The gearing throughout is steel spur gears, with teeth cut from the solid. The end truck wheels have roller bearings. The general dimensions are as shown on the plan.

Capacity.—The lifting capacity of the crane is . . . . . tons, and the guaranteed testing capacity . . . . . tons. The height of lift is . . . . . ft.

Movement.—The bridge travel is operated with a hand chain working on a 36-in. sprocket wheel, which is geared through a series of reduction gears to one pair of truck axles. The shaft to which this sprocket is geared runs along the length of the crane and is supported at intermediate points to the frame.

The trolley is moved by pulling on the suspended hoisting block.

The lifting is performed by pulling on the 3/8-in. chain of a . . . . . ton triplex hoisting block, which is part of the block mechanism.

Trolley.—The trolley is made of four single flange . . . . . in.

chilled tread wheels supported by bent plates that are curved in at the lower side and united with a pin on which the hoist block is sustained. The trolley wheels run in the outer faces of channels which form the lower chord of the crane girder.

Hoist Block and Hook.—The hoist block is forged from the best refined iron, and is amply strong enough to carry its maximum load. It swivels on hardened steel balls turning between disks.

Material.—The material of the bridge and other riveted parts is medium open hearth or Bessemer steel with an ultimate capacity of 50,000 to 60,000 lb. per square inch in tension. The maximum fiber stresses used in proportioning the crane are 10,000 lb. per square inch in compression, and 12,000 lb. per square inch in tension. A factor of safety of five is provided throughout.

Wheel Loads.—The maximum wheel load is . . . . . lb., or a total of . . . . . lb. on the two wheels at the loaded end of the crane. This weight includes the weight of the frame, machinery trolley, hoist block and suspended load.

Erection.—The crane is to be erected by the contractor, so he shall be responsible for the proper and efficient working of the machine.

Guarantee.—The contractor guarantees the crane to be made of the best material, and to be satisfactory and according to specifications in every respect. Any breakage that may occur within one year after date of contract or purchase, will be replaced by the contractor free of charge to the purchaser. It is guaranteed also to handle the working load with ease and safety.

NOTE.—The subject of "Cranes" is so extensive that it is impossible to give it any comprehensive treatment in the scope of this volume. Several treatises have been written covering all branches of the subject, and to these the reader is referred for fuller information. Weight tables for hand and power cranes may be found in Tyrrell's "Mill Buildings," and in a later edition of this book it is hoped to give the subject greater consideration. Mention is made here only to the writer's design for a simple form of hand crane which can easily be made in any structural shop.—THE AUTHOR.

CHAPTER XXVIII

YARDS AND TRANSPORTATION

The arrangement of buildings in relation to each other, with their storage and shipping facilities, is discussed to some extent in Chapter II, but further particulars of the yards and the means of transferring materials between the buildings is given here.

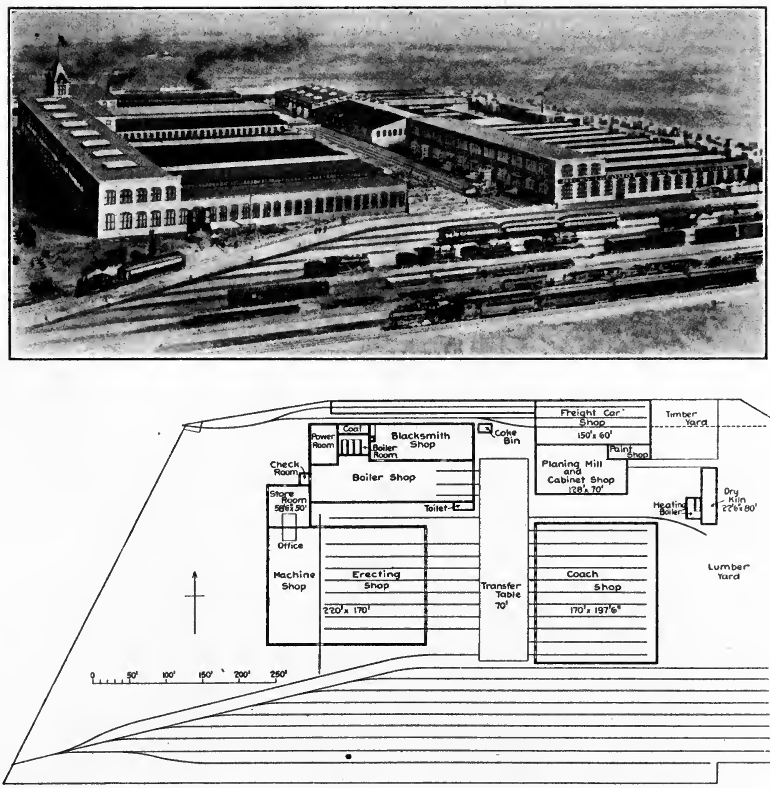


FIG. 171.—Hicks Locomotive and Car Works, Chicago Heights.

Only small shops with light products can carry on business economically without a railroad connection, for the receiving and unloading of fuel is reason enough for the presence of a

siding. The shipping of even one carload per week might very soon pay for track facilities or for a better location.

The laying out of yards (Fig. 171) includes grading, placing of sewers, water pipes, tracks, switches, engine or motor sheds, trolley lines, scale and weighing house, driveways, footwalks, fences, gates, etc. Some of these items, especially the arrangement of tracks, is of vital importance to the interest of the business.

Track Arrangement.—Tracks in manufacturing yards are of two kinds, (1) standard gauge for heavy cars, and (2) light ones for hand cars and trucks. Enough of the former kind must be used to ship and store heavy goods, and as many of the lighter ones for moving smaller parts as convenience may direct. The arrangement of tracks will depend to some extent on the kind of power and type of motors, though connection to the main line of railway will always be with standard gauge. Yard tracks may be laid out in either one of two ways, (1) with stub end sidings (Fig. 172), and (2) with a circuit or loop (Fig. 173). The first method is sufficient for small plants, and may sometimes be for larger ones if enough sidings are provided, though in large works the loop or circuit system has the greatest advantage. Circuits should have two connections to the main line and should have all the additional sidings that will ever be needed for the storage of cars, the sidings running off by a system of yard "ladders." Turntables for turning cars are usually a nuisance for they become clogged with snow and ice and leave a partially open and dangerous pit. Curves are much better, and those for standard gauge should have a radius of 235 ft. or more, so cars and locomotives will not bind, while the radius for 30-in. gauge should not be less than 40 ft.

The need of running wide gauge tracks into the buildings will depend on conditions and the methods of receiving and shipping as previously determined. Heavy goods such as structural work and machinery, which is completed in the shop ready for shipment, may be loaded by running cars into the building or by extending the shop cranes out through the end and over the shipping yards. In the former case, with cars admitted to the shop for loading, it is usually sufficient to project the tracks one or two car lengths into the shop on a stub, and after loading the car, to withdraw it again. The cost of standard gauge with rails and

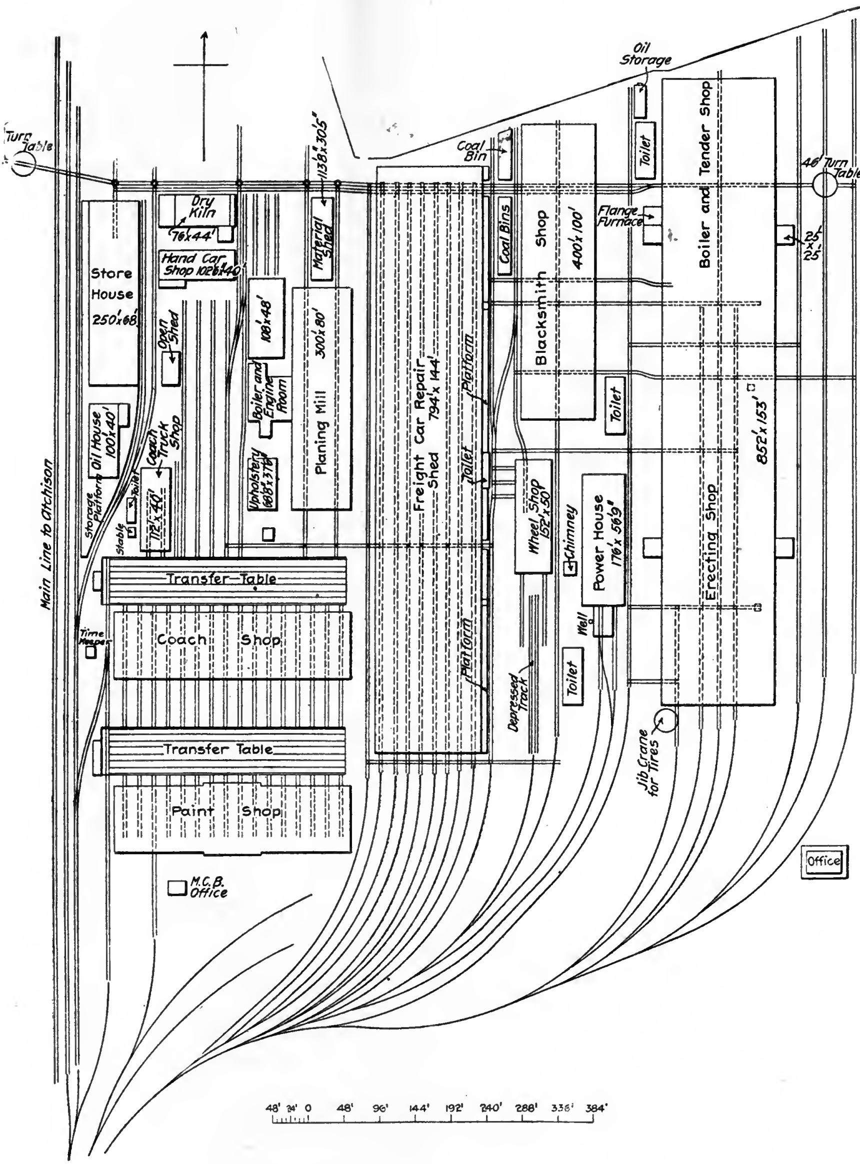


FIG. 172.—Railway shops at Topeka, Kansas.

ties may be estimated approximately at the rate of $2 per lineal foot.

Light track for service cars should be freely used about the yard and works, but adjoining ones should not be closer together than 6 ft. on centers. The distance between rails may vary anywhere from 15 in. to 4 ft. 8 1/2 in. as used for standard steam cars, though the usual width is 30 in. Rails weighing 40 lb. per yard are heavy enough, and in shops, streets or thoroughfares, the rail heads should never be above the floor or grade. Driveways about the yard or between the tracks and buildings may conveniently be paved with brick, which is easier to walk upon than stone, and offers a better foothold for horses than asphalt.

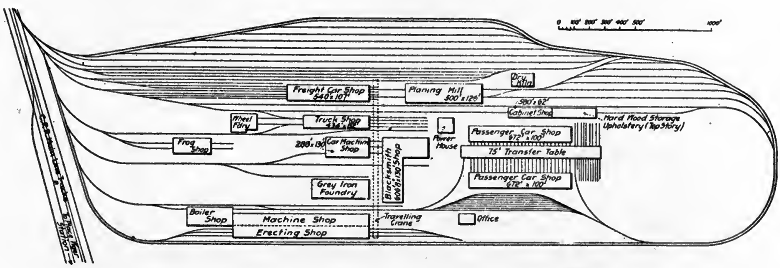


FIG. 173.—Canadian Pacific Railway shops. Montreal, Canada.

Motors.—The kinds of haulage motor used about shops and industrial works include steam, electric and compressed air locomotives, the electric type, all things considered, being the best. These can travel on the standard gauge steam tracks, even though the custom is not favored by the steam railroad officials. When the trolley wire for an electric locomotive would interfere with the movement of cranes, the locomotive can have a trolley connection through a slot in the floor, or when entering a building with the trolley on an overhead wire, the wire can be made to uncoil in advance of the locomotive and furnish it with power, the wire coiling up again as the motor recedes. A motor derrick car is also very handy about the yard for lifting and loading goods.

Compressed air locomotives are perhaps the safest about works which have much lumber or other combustible materials, but as they require a higher air pressure than used for other purposes, an additional heavy and expensive compressor is needed. With any of the above kinds of motor haulage, small industrial cars

must be supplied for the service tracks, and hand trucks with slightly rounded tires, preferably covered with rubber, are useful for moving goods promiscuously about the shops to parts not served by the narrow gauge tracks. Car-wheel treads should not be flat, but slightly tapered inward toward the flange as on standard heavy cars.

Loading and Conveying Apparatus.—Lifting and handling appliances about the yards and buildings, include traveling cranes, gantry cranes, trolleys, mono-rails, transfer tables, and moving platforms. Nearly all modern plants are equipped more or less with traveling cranes, and in metal working shops and power houses they are an economic necessity. Many works now have their whole yards covered by a system of traveling cranes on

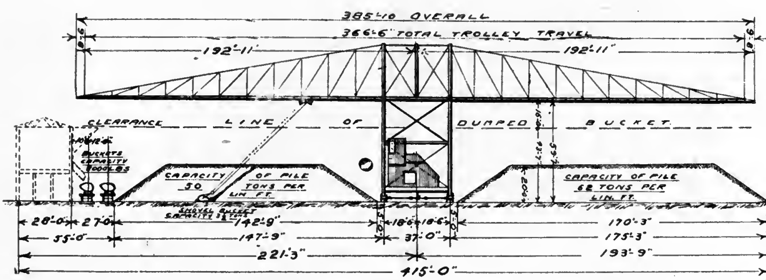


FIG. 174.—Cantilever crane.

elevated tracks. When the cranes move between adjoining buildings with girders on the wall columns, the supports then form no additional obstructions, but over larger yards where special runways must be erected, this type of crane is not so desirable. In such cases traveling gantry cranes are better. Cantilever gantries with a central tower moving on a pair of tracks, and arms overhanging the yard at each side (Fig. 174), offer the least obstruction but are not so stable as those with end supports, though some makes give excellent results.

Individual trolleys are suitable for lifting and conveying loads up to 5 or 6 tons in weight or occasionally up to 10 tons, and they have the merit of comparatively low cost but they can travel only in one general direction without lateral movement.

Mono-rail systems which are only a special kind of trolley conveyor are useful in connection with traveling cranes and can

be provided with switches and cross-overs or can travel around curves and corners. The trolley support consists of a single bar of wrought metal folded over in such shape that the trolley runs within it, and the thickness of the metal is proportioned to the load to be sustained. The track is in many respects similar to a familiar type commonly used for rolling doors. Its narrow width and light metal permits it to be curved to comparatively small radii for turning corners. This system is extensively used in multi-story buildings, especially in packing plants, where the tracks have connections with the freight elevators for transferring goods to any story.

CHAPTER XXIX

ESTIMATING

In order to illustrate methods of estimating building costs, examples are given of estimates and bids made by the writer in 1908, for two different manufacturing plants.

The first of these is for the superstructure of three metal working shops at Chicago containing:

1 Building,	125×175 ft.	1 Story and basement,	Bldg. A.
1 Building,	16×133 ft.	2 Stories and basement,	Bldg. B.
1 Building,	112×230 ft.	2 Stories and basement,	Bldg. C.

Building A.			Number of square feet of wall of different thicknesses 12 in.	16 in.	21 in.	24 in.
Brick. Front,	16 in. wall	$5\frac{1}{2} \times 175$ ft.,		1,750		
	16 in. wall	$4\frac{1}{2} \times 175$ ft.,				
	12 piers	$22 \times 2 \times 4$ ft.,				1,056
East,	16 in. wall	$5\frac{1}{2} \times 125$ ft.,		1,125		
	16 in. wall	$3\frac{1}{2} \times 125$ ft.,				
	4 piers	15 ft. $\times$ 21 in. $\times$ 4 ft.			440	
	5 piers	10 ft. $\times$ 21 in. $\times$ 4 ft.,				
West,	16 in. wall	$5\frac{1}{2} \times 125$ ft.,				
	16 in. wall	6×125 ft.,		1,437		
	4 piers	$2 \times 4 \times 19$ ft.,				304
	4 piers	$2 \times 4 \times 10$ ft.,				160
Rear,	16 in. wall	12×175 ft.,		2,100		
	12 piers	$2 \times 4 \times 11$ ft.,				528
Inside wall,	80×10 ft. $\times$ 17 in.,			800		
	175×10 ft. $\times$ 17 in.,			1,750		
	80×18 ft. $\times$ 12 in.,		1,440			
	30×10 ft. $\times$ 12 in.,		300			
	175×30 ft. $\times$ 12 in.,		5,250			
1 Stack,	16×40 ft. $\times$ 17 in.,			640		
1 Stack,	20×40 ft. $\times$ 17 in.,			800		
			6,990	10,402	440	2,048

Face brick, deduct from above at $16.00 per M.

	32×220 ft.,		7,040		
Less		12×19×14 ft.		3,192	
		12× 4×14 ft.		672	
	24×16 ft.,		384		
		15×9 ft.,		135	
	20×50 ft.,		1,000		
		12×11×3 ft.,		396	
			8,424	4,395	= 4,029 sq. ft.
					=28,200 brick

Tile wall capping, 435 lin. ft.
Fire brick, 4 in. thick 22×40 ft. 800 sq. ft. = 6,160 brick

Summary.

6,990 sq. ft. wall,	12 in. thick, at 20 bricks,	139,800
10,402 sq. ft. wall,	16 in. thick, at 26 bricks,	270,452
2,488 sq. ft. wall,	21 in. thick, at 34 bricks,	82,104
		492,356 less
		28,000 face = 464,000 bricks.

Building B.

Brick.	2 Walls 12 in. thick, 35×133 ft.			9,310	
Less	9	4×2½ ft.	90		
	13	4×9 ft.,	468		
	8	4×6 ft.,	192		
	5	6×13 ft.,	390		
				1,140	
Brick face	say 16 in. thick,			8,170×20 =	163,400
	7×120 ft.				21,800
					185,200

Tile Coping 130 ft. for 12 in. wall.
Face brick 40 M (deduct from above).

Building C.

Brick.

12-in. face wall, 684×34 ft.				23,256
	50 Pilasters	2½ ft. ×8 in. ×30		
Less	64	11×8 ft.,	5,632 sq. ft.	
	32	11×3 ft.,	1,056	
	32	10×9 ft.,	2,880	
	16	10×2 ft.,	320	
				9,888
				13,368 sq. ft. net

12-in. inside wall	124×42 ft.	
	40×42 ft.	
	50×42 ft.,	9,996
	24×42 ft.	
	16×52 ft.,	832
		24,196

400 ft. tile wall coping 12-in. wall.

Fire brick 4 in. thick, 20×50 ft.

Face brick	434×34 ft.	=15,436
Less 64	8×11 ft.	5,760
		9,676×7 =68 M. Deduct from above.

Summary.

12-in. wall	24,200 sq. ft. at 20,	484,000
8-in. wall	3,750 sq. ft. at 14	52,500
		536,500

Brick summary.

	Common	Face	Fire	Tile coping
Building A.,	464,000	28,000	6,160	435 lin. ft.
Building B.,	145,000	40,000	....	130 lin. ft.
Building C.,	468,000	68,000	7,000	400 lin. ft.
	1,077,000	136,000	13,160	965 lin. ft.

Building A.

Stone.

2 stone chimney caps, 5×5 ft. 50 sq. ft.

1 stone chimney cap, 3×3 ft., 9 sq. ft.

Coping 10 in.×2½ ft., 415 lin. ft. 830 sq. ft.

300 lin. ft. stone belt course 5×8 in.

21 window sills 5×8 in. ×12 ft. long.

Building B.

Stone.

110-ft. coping 10 in. ×2 ft. 0 in.
130-ft. coping 10 in. ×2 ft. 2 in.
6 stone gate posts $3\frac{1}{2}\times3\frac{1}{2}\times10$ ft. =735 cu. ft.
62 stone sills 5ft. 0 in.

Building C.

Stone.

464-ft. wall coping, 10 in. ×2 ft. 0 in.
96 stone sills, 10 ft. long.
Entrance Ashlar, 220 sq. ft.

Summary of stone.

1119-ft. coping,	10 in. ×2 ft. 5 in.	=2,220 cu. ft. at	$1.20	$2,660
1822-ft. sill,	5×8 in.,	= 600 cu. ft. at	.60	1,092
2 chimney caps,	5×5 ft.,	= 50 cu. ft. at	2.00	100
1 chimney cap,	3×3 ft.,	= 9 cu. ft. at	2.00	18
6 gate posts,	$3\frac{1}{2}\times3\frac{1}{2}\times10$ ft.,	= 735 cu. ft. at	1.20	882
Entrance Ashlar,		220 sq. ft. at	.60	132
Setting,		3,724 cu. ft. at	.30	1,117
				$6,001

Building A.

Tile partitions.

61×16 ft. of 6-in. tile, 976
36×10 ft. of 6 in. tile, 360

1,336
60×16 ft. of 8 in. tile, =960

Building C.

Tile.

Second story,	180 ft., double	6 in. tile wall,	18 ft. high,	6,480 sq. ft.
Second story,	58 ft., single	6 in. tile wall,	14 ft. high,	812 sq. ft.
First story,	180 ft., double	6 in. tile wall,	15 ft. high,	5,400 sq. ft.
First story,	124 ft., single	6 in. tile wall,	15 ft. high,	1,860 sq. ft.
Basement,	161 ft., double	6 in. tile wall,	9 ft. high,	2,898 sq. ft.
				17,450 sq. ft.

Summary of Tile.

6 in. 18,790 sq. ft.
8 in. 960 sq. ft.

Building A.

Concrete.

Cellar paving 6 in. thick
With expanded metal 4 in. No. 10 } 125×175 ft. = 21,875 sq. ft.
Granolithic surface 1 1/4 in. thick, 125×175 ft.

Building A.

Reinforced Concrete. Design by Contractor.

Vents	16×30 ft.	480
	13×36 ft.	468
	16×78 ft.	1,248
		2,196
Floor,	78 ft.×110 ft. cellar	8,580

Granolithic surfaces on 78×110 ft.

Building B.

Concrete paving similar to A.
16×133 ft. = 2,128

Building C.

Reinforced concrete.

10 – 24×13 ft. = 3,120
1 – 8× 8 ft. = 64
Cellar pavement, 112×230 ft.
Area, 3×230 ft. } $7\frac{1}{4}$ in. thick with Ex. met. 4 in. No. 10 D. 26,450 sq. ft.
Over vault, 12×12×2 ft. = 288
Press pit 900 sq. ft. 3 in. on Ex. metal.

Plain concrete.
Area wall 230 – 3×$1\frac{1}{2}$ ft. 1,035 cu. ft. = 40 cu.yd.

Summary of concrete.

	Cellar floor and surface with ex. metal	Roof	Floor
Bldg. A,	21,875	2,200	8,580
Bldg. B,	2,130		
Bldg. C,	26,450	3,184	288
	50,455 sq. ft.	5,384 sq. ft.	8,868 sq. ft.

Cellar floor,	50,455 sq. ft.	=5,606 sq. yd. at 18=	8,658	
Roof,	5,384 sq. ft.	at 25=	1,346	
Second floor,	8,868 sq. ft.		2,474	4,155
3 in. wall,	900 sq. ft.		135	
Area wall,	40 cu. yd.		200	
			12,813	

Building A.

Carpentry. No. 1, L. L. y. p. s. 3. s.

9	6×12 in.	175 ft.	9,450
17	6×12 in.	64 ft.	6,528
55	2×10 in.	80 ft.	7,333
37	10×12 in.	65 ft.	24,050
11	8×14 in.	14 ft.	1,440
26	6×14 in.	14 ft.	2,600
58	10×14 in.	30 ft.	20,300
			71,701 ft. B. M.

Sheathing.

Roof,	$1\frac{5}{8}\times6$ in.	125×175 ft. matched y.p.	21,875
Second,	$2\frac{3}{4}\times6$ in.	80×110 ft. matched y.p.	8,800
First,	$2\frac{3}{4}\times6$ in.	42×175 ft. matched y.p.	7,350

Maple flooring, $1\frac{1}{8}\times3\frac{1}{4}$ in. $\times175\times42$ ft. matched side and end 7,350 sq. ft.
No. 1 maple in office
Building paper, $175\times42=7{,}350$ sq. ft.

Erect mill work.
Erect hardware.

Coal bunkers, 48 ft. long $\times$ 9 ft. high.

20	$4\times$ 6 in. $\times9$ ft.,	360
6	6×10 in. $\times9$ ft.,	270
	2 in. plank, 48×9 ft.,	960
150 ft.	6×8 in.,	600
		2,190 ft. B. M.

Weights and cords.

Building B.

Carpentry.

53–	8×14 in. ×	18 ft. =	8,904
45–	7×14 in. ×	18 ft.	6,615
23–	6×12 in. ×	18 ft.	2,484
2–	8×12 in. ×	90 ft.	1,440
1–	8×12 in. ×	132 ft.	1,064
2–	8×14 in. ×	90 ft.	1,680
1–	8×14 in. ×	120 ft.	1,120
2–	4× 8 in. ×	133 ft.	704
2–	7×14 in. ×	44 ft.	735
1–	10×12 in. ×	44 ft.	440
			25,186

$\left\{\begin{array}{l}\text{6 in. floor, } 8\times278 \text{ ft.}\\ 6\times3 \text{ in. on edge}\\ \text{with } \frac{3}{8} \text{ in. open joint}\end{array}\right\}$ 12,000

$2\frac{3}{4}$ in. flooring, First floor, 16×133 ft. = 2,000 sq. ft.
second floor, 16×133 ft. = 2,000 sq. ft.
$1\frac{3}{4}$ in. flooring, roof, 16×133 ft. = 2,000 sq. ft.
$1\frac{1}{8}$ in. finish flooring, first floor, 16×133×2. Maple = 4,000 sq. ft. net.
Building paper, 16×133×2 ft. = 4,000 sq. ft.
Weights and cords for all 3 buildings.
Weights 460 windows at 60 lb., 27,600 lb., say 15 tons at $30 = $450
Cords, 460 windows at 20 ft. 9,200 ft. at .04, 350

$800

Building C.

Carpentry.

Roof,	50–	6×12 in.	112 ft.	33,600
Second,	66–	8×12 in.	109 ft. 5	7,550
First,	12–	10×14 in.	68 ft.	9,520
	44–	10×14 in.	42 ft.	21,560
	36–	6×14 in.	42 ft.	10,504
	54–	12×16 in.	27 ft.	23,328
	16–	10×14 in.	54 ft.	10,080
	20–	6×14 in.	56 ft.	7,840
				173,982

Flooring and Roofing.

$1\frac{3}{4}$ Roof	109×227 ft.	=24,743 sq. ft.
Less 10	13×24 ft.	3,120
		21,623
$2\frac{3}{4}$ in. flooring second,	109×227 ft.	24,734
Less 4	10×20 ft.	800
		23,943
First,	109×227 ft.	24,743
Less 4	10×20 ft.	800
		23,943

$1\frac{1}{8}$ in. maple, first and second floors, 24,000×2 sq. ft. = 48,000 sq. ft.
Building paper, 48,000 sq. ft.
Wood bolts, spikes, nails, etc. Total lumber 624,000 ft. B. M.

Floor Anchors.

Using 10 lb. for 1,000 ft. B. M. framing timbers.
Using 30 lb. for 1,000 ft. B. M. flooring.
285 M framing at 10 lb. nails per M = 2,850 lb.
400 M flooring at 30 lb. nails per M = 12,000 lb.

14,850 = 148 kegs

Or, if one keg used for every 3,000 ft. B. M.

$$\text{No. kegs} = \frac{68,500}{3,000} = 228 \text{ kegs.}$$

Carpentry Summary.

	Framing timber	$1\frac{3}{4}$×6	$2\frac{3}{4}$×6	Maple	Paper	3×6 in.
Building A....	73,890	21,875	16,150	7,350	7,350	
Building B....	25,186	2,000	4,000	4,000	4,000	12,000
Building C....	173,982	21,623	48,000	48,000	48,000	
	273,058	45,498	68,150	59,350	59,350	12,000

Carpentry Summary, continued.

Framing timber,	285,000 ft. B. M. at	$35.00	9,975
Flooring, $1\frac{3}{4} \times 6$,	57,000 sq. ft. gross	.05	2,850
Flooring, $2\frac{3}{4} \times 6$,	85,100 sq. ft. gross	.08	6,808
Flooring, $1\frac{1}{8}$-in. maple,	75,000	.071	4,600
Paper,	59,400 sq. ft. gross	.005	300
Erect hardware on,	460 windows 23 doors	.50	240
Window weights,	15 tons	30.00	450
Window cords,	9,200 lin. ft.	.04	368
Spikes, bolts, etc,.	200 kegs	3.00	600
Anchors, etc.,	5,000 lb.,	.04	200
Hauling,	1,400 tons	.75	1,050
Hoisting,	685,000	.50	342
			26,733

List of Sub-bids

Iron and Steel:

Bid A	$45,725
Bid B	40,620
Bid C	38,550
Bid D (stairs, guards, ladder only)	6,085

Iron Doors:

Bid A	9,589
Bid B	9,162

Painting:

Bid A	3,856
Bid B	2,897
Bid C	2,400

Roofing:

Bid A	1,613
Bid B	1,495
Bid C	1,400

Plumbing:

Bid A	8,875
Bid B	8,160
Bid C	6,440

Plastering:

Bid A	760
Bid B	730

Mill Work:

Bid A	5,500
Bid B	5,025

Glazing:

Bid A	1,587
Bid B	1,352

Terra Cotta:

Bid A	1,370
Bid B	1,125

Marble:

Bid A	372

Sheet Metal:

Bid A	4,280
Bid B	3,531
Bid C	2,888
Bid D	2,730
Bid E	2,188
Bid F	2,059

Reinforced Concrete and Cellar Floor:

Bid A	8,755

ESTIMATE SUMMARY

Superstructure Only

Three Factory Buildings, Chicago

1 building, 125×175, 1 story and basement, A.
1 building, 16×133, 2 story and basement, B.
1 building 112×230, 2 story and basement, C.

Superintendent (4 months)	$ 560
Foreman	500
Watchman	100
Office and sheds	200
Telephone	50
Barricade, 650 ft. (lineal)	100
Accident insurance	700
Fire insurance	100
Remove rubbish and haul scaffolding	500
Water permit	50
5 temporary stairs	100
Plant	500
Brick, common (1077 M. at $20.00)	21,540
Brick, face (136 M. at $45.00)	6,120

Brick, fire (13 M. at $40.00)	520
Tile coping (965 l. f. at .20)	193
Partition tile, 6 in. (18,800 sq. ft. at .15)	2,820
Partition tile, 8 in. (960 sq. ft. at .17)	163
Stone, 3800 cu. ft.	6,000
Concrete cellar floor (7 1/4 in. at .18)	8,658
Concrete, reinforced	4,155
Carpentry	27,000
Mill work (Bid B)	5,025
Mill work setting, 30 per cent	1,675
Terra cotta (Bid B)	1,125
Terra cotta setting, 20 per cent	220
Plastering (Bid B.)	730
Painting (Bid C)	2,400
Glazing (Bid B)	1,352
Marble and mosaic (Bid A)	372
Sheet metal (Bid D)	2,730
Roofing (Bid C)	1,400
Structural steel and iron (Bid C)	38,550
Iron doors (Bid B)	9,162
Plumbing (Bid C)	6,440
Incidentals	3,000
	$154,810
Profit, 5 per cent	7,740
	$162,550

EXAMPLE NO. II

The second etimate given here is for an automobile factory, 75 feet wide, 865 feet long, and four stories high; with reinforced concrete frame, and walls with brick facing, but composed chiefly of glass. Alternate design also, on steel framing.

Excavation:

General, $100 \times 78 \times 8\frac{1}{2}$ ft. $= 66,300$ cu. ft. $= 2,455$ cu. yd.
Trench, 1900 ft. at $1\frac{1}{2} \times 4\frac{1}{2}$ ft. $= 12,825$ cu. ft.
Piers, 88 at $7\frac{1}{2} \times 7\frac{1}{2} \times 4\frac{1}{2}$ ft. $= 22,176$ cu. ft.
88 at $6\frac{1}{2} \times 6\frac{1}{2} \times 4\frac{1}{2}$ ft. $= 16,720$ cu. ft.
7 at $2\frac{1}{2} \times 2\frac{1}{2} \times 4\frac{1}{4}$ ft. $=$ 196 cu. ft. $= 1,930$ cu. yd.

Reinforced Concrete:

4 in. floor slabs.

$$\left.\begin{array}{l}\text{3 floors, } 74 \times 860 \text{ ft.}\\ \text{1 roof, } 74 \times 860 \text{ ft.}\end{array}\right\} = 254,560 \text{ sq. ft.}$$

6 in floor slabs, 60×74 ft. $=$ 4,440 sq. ft.
178 beams, 12×18 in. $\times$ 70 ft. $=$ 12,460 lin. ft.
44 beams, 6×12 in. $\times 780$ ft. $=$ 34,320 lin. ft.

Wall Beams:

780 ft. beams = 18×30 in.
1,560 ft. beams = 16×24 in.
780 ft. beams = 16×48 in.
2,920 ft. beams = 8×24 in.

6,040

Columns:

88 inside columns, 16×16 in.×52 ft. = 4,576 lin. ft.
104 outside columns, 16×24 in.×52 ft. = 5,408 lin. ft.

Column Piers:

88 piers, 7×7 ft.×18 in. } = 11,220 cu. ft.
88 piers, 6×6 ft.×18 in. }
860 ft. parapet, 2½ ft.×8 in. = 1,290 cu. ft.
and 2,700 sq. ft. = 700 cu. ft.

1,990 cu. ft.

Reinforced Concrete Summary.

4 in. slab,	254,560 sq. ft.	84,853 cu. ft.
6 in. slab,	4,440 sq. ft.	2,220 cu. ft.
12×18 in. beam,	12,460 lin. ft.	18,690 cu. ft.
6×12 in. beam,	34,320 lin. ft.	17,160 cu. ft.
18×30 in. beam,	780 lin. ft.	2,925 cu. ft.
16×24 in. beam,	1,560 lin. ft.	4,160 cu. ft.
16×48 in. beam,	780 lin. ft.	4,160 cu. ft.
8×24 in. beam,	2,920 lin. ft.	3,890 cu. ft.
Cols. 16×16 in.,	4,576 lin. ft.	9,152 cu. ft.
Cols. 16×24 in.,	5,408 lin. ft.	13,500 cu. ft.
Cols. bases,		11,220 cu. ft.
		171,930 cu. ft.
Forms for slabs,		260,000 sq. ft.
Forms for beams,		52,820 lin. ft.
Forms for cols.,		9,980 lin. ft.

Cost.

Concrete,	172,000 cu. ft.	at	$.23	=	$ 39,560
Steel,	576 tons	at	50.00	=	28,800
Steel hauling,	576 tons	at	.50	=	288
Steel erecting,	576 tons	at	4.00	=	2,300
Forms, slabs,	260,000 sq. ft.	at	.06	=	15,600
Forms, beams,	52,800 lin. ft.	at	.30	=	15,840
Forms, cols.,	10,000 lin. ft.	at	.40	=	4,000
Damp proof,	3,200 sq. ft.	at	.05	=	160
1 in. surfacing,	260,000 sq. ft.	at	.05	=	7,800
16 stairs, 4 ft. wide,					2,400
					$116,748

Brick. Area of wall in square feet.

Foundation		8-in. wall	12-in. wall	17-in. wall
Tunnel 8-in. wall, 18 ft. × 78 ft.	=	1,404		
210 ft. 8-in. wall, 8 ft.	=	1,680		
260 ft. 17-in. wall, 10 ft.	=			2,600
20 ft. 17-in. wall, 10 ft.	=			200
370 ft. 8-in. wall, 7 ft.	=	2,590		
870 ft. 12-in. wall, 7 ft.	=		6,090	
1,470 ft. 8-in. wall, 7 ft.	=	10,290		
		15,964	6,090	2,800

First Story.		8-in. wall	17-in. wall
44 pilasters, 5 ft. × 8 in. thick × 11 ft. high	=	2,420	
360-ft. wall, 8 in. thick × 14 ft. high	=	5,040	
50-ft. wall, 17 in. thick × 14 ft. high	=		700
210-ft. wall, 8 in. thick × 14 ft. high	=	2,940	
80-ft. wall, 17 in. thick × 14 ft. high	=		1,120
		10,400	1,820

Second Story.			
210-ft. wall, 8 in. × 12 ft.	=	2,520	
360-ft. wall, 8 in. × 12 ft.	=	4,320	
80-ft. wall, 17 in. × 12 ft.	=		960
80-ft. wall, 17 in. × 12 ft.	=		960
		6,840	1,920

Third story, same as second.
Fourth story, same as second.
Pent house. Solid brick walls.

4 pt. ho. 30 × 4 ft. × 8 in. = 480
6 pt. ho. 60 × 15 ft. × 8 in. = 5,400

Brick Summary.

Solid wall in foundation.

15,964 sq. ft. wall,	8 in. at	14 bricks	=	224,000 bricks
6,090 sq. ft. wall,	12 in. at	21 bricks	=	128,100 bricks
2,800 sq. ft. wall,	28 in. at	28 bricks	=	78,400 bricks
				430,500 bricks

Hollow and face brick.	8-in. wall	17-in. wall
First story,	10,400 sq. ft.	1,820 sq. ft.
Second story,	6,840 sq. ft.	1,920 sq. ft.
Third story,	6,840 sq. ft.	1,920 sq. ft.
Fourth story,	6,840 sq. ft.	1,920 sq. ft.
Pent house,	5,880 sq. ft.	
	36,800 sq. ft.	7,580 sq. ft.

36,800 sq. ft. 8-in. wall at 14 bricks	515,200 bricks
7,580 sq. ft. 17-in. wall at 28 bricks	212,240 bricks
	727,440 bricks

Face brick = 40,100,
Hollow brick = 727,440 − 40,100 = 687,340 bricks.
Reinforced concrete: design with steel framing.

Floors and roof, 4 74×860 ft.

4-in. floor slabs,	254,600 sq. ft.	=	84,853 cu. ft.
6-in. floor slabs,	4,440 sq. ft.	=	2,220
12×18-in. beam,	12,460 lin. ft.	=	18,690
6×12-in. beam,	24,960 lin. ft.	=	12,480
Column bases,	416 cu. yd.	=	11,220
			129,463

Forms for slabs = 260,000 sq. ft.
Forms for beams = 37,420 lin. ft.

Cost.

Concrete, 130,000 cu. ft.	at	$.30	=	$39,000
Steel, 400 tons	at	50.00	=	20,000
Steel, 400 tons, hauling	at	.50	=	250
Steel, 400 tons, setting	at	4.00	=	1,600
Forms, slabs, 260,000 sq. ft.	at	.06	=	15,600
Forms, beams, 38,000 lin. ft.	at	.30	=	11,400
1-in. surfacing, 260,000 sq. ft.	at	.03	=	7,800
16 stairs, 4 ft. wide	at	150.00	=	2,400
				$98,050

Brick: design with steel framing.

16-in. wall beams,	6,200 lin. ft.	15,135 cu. ft.
16-in. wall cols.,	5,408 lin. ft.	13,500 cu. ft.
		28,600 at 21 = 600,600 bricks

Above divided as follows:				
Face brick, 100,000	at	$45.	=	$4,500
Common bricks, 500,000	at	18.	=	9,000
230 stone sills, 17 ft. long = 3910 ft.	at	.50	=	1,955
88 Col. casings, 4 ft. around × 50 ft. = 352 M.	at	$18.	=	6,336
				21,791

LIST OF SUB-BIDS

Round high-carbon steel bars

3/ 4to 1/4 in.,	$1.52 1/2	
5/8 in.,	1.57 1/2	
1/2 in.,	1.62 1/2	F.O.B. in car-load lots
3/8 in.,	1.77 1/2	

List of Sub-bids, continued.

Sheet Metal and Roofing:

	Covering Metal only	Doors only	Total For conc. design	Total For steel design
Bid A. Gutters, cornice, flashing, conductor heads	$1,000	......	......	......
Bid B:				
For concrete	1,483	$931	......	......
For steel frame	1,834	......	......	......
Bid C	995	1,025	......	......
Bid D	1,161	......	......	......
Bid E		......	$2,246	$2,884
Bid F		......	3,454	4,172
Bid G		......	3,000	3,408
Bid H		......	2,900	3,800
Bid I		......	3,063	3,609
Bid J		......	3,448	3,905

Glazing:

Bid A.. $3,725

Painting:

	Painting and glazing	Painting only
Bid A	$7,480	......
Bid B		$4,300
Bid C		4,500
Bid D		4,656
Bid E	8,300	......
Bid F	9,150	......
Bid G	8,426	......
Bid H	9,925	......

Carpentry:

	Mill work only	If windows are deducted	Total
Bid A	....	$4,000	$19,959
Bid B	....	4,133	17,482
Bid C	$10,485	......	....
Bid D	....	......	16,431
Bid E	....	......	15,134

Heating:	As per plan	With asbestos covering	Magnesia covering	Air cell covering
Bid A	$19,308	$18,108	$22,208	....
Bid B	14,684	13,907	....	....
Bid C	16,300	16,500	15,000	$14,300
Bid D	15,664	15,044	....	....
Bid E[1]	15,700	....	....	....
Bid F	14,939	14,611	....	....

Plumbing:	Per plan	Special
Bid A	$10,287	$ 8,987
Bid B	8,974	....
Bid C	....	11,482
Bid D	12,535	....

Miscellaneous Iron:	F. O. B.	Erected
Bid A	$5,982	....
Bid B	....	$8,279
Bid C	3,324	....
Bid D	6,859	....

Structural Steel (for steel frame design)	F. O. B.	Erected
Bid A	....	$86,159
Bid B	....	82,370
Bid C	$72,950	86,600
Bid D	75,000	....

Excavating:

Bid A:

Grading	$2,420
Crock sewer for drainage	2,230
12-in. crock ducts for heating	735

[1] Vacuum system, $17,402, deduct $270 if air cell is used in place of magnesia pipe cover.

ESTIMATE SUMMARY

For Automobile Factory with Concrete Framing

Excavation, general,	2,455 yds.	$ .50	$ 1,227
Excavation, trench,	1,930	.50	965
Reinforced concrete,	172,000 cu. ft.	.23	39,560
Steel F. O. B	576 tons	50.00	28,800
Steel hauling,	576 tons	.50	288
Steel setting,	576 tons	4.00	2,300
Forms, slabs,	260,000 sq. ft.	.06	15,600
Forms, beams,	52,800 lin. ft.	.30	15,840
Forms, columns,	10,000 lin. ft.	.40	4,000
1-in. surfacing,	260,000 sq. ft.	.03	7,800
16 concrete stairs, 4 ft. wide		150.00	2,400
Basement floor,	56,000 sq. ft.	.14	7,840
Brick, common,	432,000	18.00	7,776
Brick, hollow,	687,300	16.00	11,000
Brick, face,	40,000	45.00	1,800
Brick, fancy face,	3,100	80.00	240
Tile coping,	210 lin. ft.	.25	50
Hydrolithic coating,	7,000 sq. ft.	.04	280
Stone sills, 17 ft. long	43	.50	360
Cement ceiling wash,	300,000 sq. ft. at	.005	1,500
Iron work, F. O. B.,			4,000
Iron work, erection, 20 per cent.,			800
Kinnear doors,			775
Mill work, erected,			10,300
Tin doors and covering			2,250
Hardware, pivots and screws,			1,200
Hardware, fire door fittings,			300
Painting,			3,400
Glazing,			3,500
Sheet metal and roofing (sub-bid E),			2,250
Plumbing,			8,200
Heating,			14,000
Superintendent for 15 months at $200,			3,000
Foreman for 15 months at $150,			2,500
Watchman,			1,000
Telephone,			100
Water,			500
Rubbish clearing,			1,000
Water closet,			50
Storage sheds,			500
Insurance,			400
Liability,			2,500
Bond, 1 per cent. on 1/4 of contract,			750
Temporary stairs, 10 sets at $50			500
Tools and plant,			5,000
Traveling expense,			200

Building permit,	300
Incidentals, 1 per cent.,	2,500
176 borings,	500
	$221,843
Profit, 5 per cent.,	11,100
	$232,943

CHAPTER XXX

CONSTRUCTION

Having completed all the designs and specifications for a plant, it is then the duty of the engineer to secure estimates and tenders, to place or assist in placing the contract for construction and to superintend the work.

Construction work may be carried on either under salaried superintendents employed by the owner, or the work may be given out in contracts. In the first method, the superintendent must employ men in the various trades, buying only such goods as he is unable to produce. When construction work is done by a contractor, he may be paid in any one of the following ways:

1. A lump sum for the whole work.
2. Cost price plus a percentage.
3. Cost price plus a fixed sum.
4. Cost price plus a percentage in inverse proportion to the cost.

Each of these methods has some advantages, No. 1 being the simplest to keep track of, and on which to make final settlement. With No. 2 there is always the incentive for the contractor to swell the cost as his own profits increase in proportion, but in No. 3 this incentive disappears, for the contractor's profit is fixed and independent of the cost of the building to the owner. In No. 4 it is plainly to the contractor's interest to keep the cost down to a minimum, for the less the owner has to pay, the more the contractor receives.

Estimates and Tenders.—A careful selection should be made when sending out invitations for tenders, that bids may be received from people in good standing, who will do good work in an honest way. In order to avoid local combinations, or the collusion of bidders, invitations should be sent to concerns widely separated from each other. The engineer is generally better able than the owner to select the bidders, for an acquaintance with the builders is part of his business, but the owner will probably want prices from people that he knows. If bids are received from a

few general contractors on the work as a whole and on the different branches of work from sub-contractors, the engineer will then know the cost in detail, and he can award the work to a general contractor in one part, or separately to sub-contractors, as economy and expediency may direct. He should receive unit prices for any kind of work, such as foundations, which may ultimately be more or less than shown on the drawings. If given out in many parts, some one of the sub-contractors must be placed in charge, and his contract must be so worded, with extra compensation for such service.

If inquiries are made by contractors respecting any uncertainties in the plans or specifications, they should be answered by duplicate letters, sending a copy to each bidder, that all may have exactly the same data and information. Sufficient time should be given for making careful estimates, for if hurried too much, contractors will add a percentage for uncertainties, and bids will be unreasonably high. Bids should be submitted in sealed envelopes plainly marked on the outside with the word "Tender", so they will not be opened until the proper time, a definte date having been previously set by the engineer, after which no further bids would be received. A blank form of contract should be enclosed with the invitations for tenders, so the contractor may see just what he is expected to sign. This contract should be drawn up by an attorney, from data and requirements supplied to him by the engineer and owner.

When time for receiving bids has expired, and they are all in possession of the engineer, they should then be opened by the engineer and owner together, and the various items tabulated for easy comparison, and in making such comparison it must be carefully noted just what is included in the price. The lowest bids by containing something that is not required sometimes appear to be high, and their relative values, are not appreciated until they are all thoroughly examined as to the work included.

Contracts.—The engineer should remember that up to this time, contractors expecting or hoping to secure profitable work, have been free with offers and promises and have probably shown nothing but good will. But with the signing of a contract, new conditions begin, for motives are now different, the contractor desiring to make the largest possible profit for himself, and the owner to get the best building he can for the least money and to get it at the time agreed upon. As the mechanical equipment is

so different to the building construction, the installation of this is usually let in a separate contract. This will include the heating, lighting, plumbing, power and water supply, fire protection, and elevators. These are wholly the designs of mechanical engineers.

Superintendence.—This work may be done either by the owner with the assistance of a salaried superintendent, or under the direction of the engineer. The latter method is without question the best, for the man who produces a design certainly knows better than any one else, how he wants it carried out.

Engineers and architects who give their best thought to questions of design usually have associated with them men who are efficient in superintendence, and many of the larger offices have regularly organized departments for construction and superintendence. Yards and grounds must be laid out with their tracks and sidings, buildings erected and equipment installed, including cranes, special machinery and mechanical installation. As the work progresses monthly estimates and reports of the amount of work done must be made by the engineer and submitted to the owner, for on these the contractor receives his progress payments. Photographs should be freely made, as they are a sure record of conditions, and often avoid or settle future disputes. Harmony in dealings is always desirable, and yet the engineer must not always conciliate merely to preserve peace.

When construction is completed and the plant finished in all its parts, the site should be put in a clean and neat condition ready for acceptance by the owner. Final estimates must then be made by the engineer, and when the work has been accepted and paid for, the engineer's duties terminate.

CHAPTER XXXI

WELFARE FEATURES

A book on modern factories would not be complete without reference to the provisions which are now so generally made for the comfort and welfare of employees. Such measures are introduced not for philanthropic but for purely commercial reasons, because "it pays." Under agreeable conditions, men and women will do more and better work than they would if uncomfortable or dissatisfied. Establishments have found that in order to produce economically, they must permanently retain a large proportion of their operatives because the constant training of new ones is too expensive. Attractive conditions are therefore created to draw and hold employees and keep them contented, in order to increase their productiveness and efficiency. It is difficult to compute the money value of this increase, but there is no doubt that willing and cheerful workers can do more than those who labor under compulsion.

The subject will be discussed under the following headings:

1. Social relations.
2. Health conditions.
3. Pleasant surroundings.
4. Material benefits.
5. Educational advantages.
6. Opportunity for recreation.

Social Relations.—The beginning of a new era in factory construction was the outgrowth of necessity. That old time friendship and acquaintance which once existed between owner and employee, had long since ceased; and in many cases, in order to earn their daily bread, men were driven by necessity to work in dirty and grimy shops, going daily to their work with no more willingness than would be aroused in going to a prison. Under such conditions they gave only enough service to hold their place, and changed often from one factory to another, to relieve the drudgery and monotony of life. Little or no interest was shown in them, and constant friction existed between the

workmen and their foremen who were intolerant and domineering, much like slave drivers. Under the lash of necessity, the sullen worker produced only when watched and driven, and balked at every opportunity. When conditions finally became intolerable for the worker, and without profit to the owner, a change was inevitable.

Conditions in some places have now swung almost to the other extreme, and welfare features are introduced to such an extent as to detract attention from the company's business. Large industries now make the interest of their workers a definite part of their business, and for this purpose a welfare manager and social secretary are appointed, one each for the men's and women's departments respectively. The duty of these persons is to study and care for the workers needs, and to act as intermediary between them and the owners. Diplomatic persons in these positions soon gain general confidence, and men and women will freely tell their wants to them, with prospect of relief. Under the new and better régime, men and women treated as human beings have regained self respect. Women workers, who were formerly all "girls," "hands," or "help," now receive the more respectful "Miss," and men, when passing through the women's workrooms, remove their hats as they would at home. Under these conditions employers rightfully expect a better education in those that they employ, and in many factories graduation from a high school is now one of the necessary qualifications.

The attitude of the factory to the public is also changed, for a welcome to visitors is now a common and definite policy. Reception rooms are provided and furnished, and guides are delegated to conduct persons about, often meeting visitors with a conveyance at the nearest depot, and escorting them to the works. Balconies or galleries afford a panorama of the work in operation, and elevators lead to an observation tower where a view is obtained of the plant and its surroundings. New factory conditions are so greatly appreciated by the public that their owners or managers are usually entitled to respect and confidence. One modern and almost ideal plant for which the writer made elaborate plans was so highly esteemed by the citizens that the return of its president from a world tour was accompanied by a great demonstration. A special train with a hundred representative men went out to meet him and escort

him home and 40,000 people paraded the streets in his honor and presented him with a loving cup.

Health Conditions.—No argument is needed to show that healthy bodies are essential to efficient work. The following health requirements should therefore be maintained:

1. General cleanliness of buildings and occupants.
2. Abundance of washing and bathing facilities.
3. Good light, and pure air of the right temperature and humidity.
4. Regular working hours, with sufficient time for rest and recreation.

With these requirements fulfilled, there should be enthusiasm during working hours.

In order to start right, applicants should pass a health examination before being given employment.

The building should be swept daily, and washed out once a week, and this work will require the service of one janitor for about fifty employees, or four for every acre of floor space. Spitting should be prohibited. In some plants where a large number of women are employed, they may be supplied with clean aprons and half sleeves twice per week. This will average about ten articles per week for the laundry for each person. In large establishments a steam laundry may be maintained, and to avoid disagreeable odors it should be on an upper floor. Windows should be regularly cleaned and curtains renewed when they are soiled. In shops as elsewhere, order and cleanliness promote self respect, but interest, inspiration and energy are lost when working amid dirty surroundings.

Lavatories and shower baths are now prescribed by law in many states, and some shops permit employees to take two baths per week in summer and one in winter during working hours. Occupants in some departments of paint works are required to bathe daily to prevent possibility of lead poisoning. Hot and cold water, towels and soap should be provided free, for if any charge is made, their general use will be limited. Plants where light machinery is made should have one shower bath for every twenty to thirty persons, and some foundries have one bath and shower for every man. A swimming tank in the basement may be supplied for those who like to use it.

Good light and pure air are essential to health. A vacuum system should be used in polishing rooms, and suction hoods

hung over tables where dust or odors are evolved. This is especially important in shops making cloth or cotton goods, where the dust often produces throat and lung disease. In one cotton mill in England, no less than 74 per cent. of all the workers were thus affected. Air can be cooled in summer by passing it through a spray chamber before forcing it up through the building, and at forges and rolling mills this may be actual economy, as it permits continuous instead of spasmodic work before the hot and open fires.

Energy should be conserved for useful purposes, and operatives and especially women, should, in multi-story buildings have free use of elevators. Women should also have high-backed chairs and footstools for occasional or continuous use, and they should be dismissed ten to fifteen minutes earlier than men at night and come later in the morning, so they may find seats in the street cars. Some shops also give morning and afternoon recess of ten minutes for relaxation. Shops employing women should have a rest room with comfortable chairs and lounges, and large works often have a regular nurse in attendance. This room should contain a case of medicines, plasters, bandages and other things needful in emergencies, and arrangements should be made with physicians that one will always be within immediate reach. Foremen should be instructed in methods of rendering aid in case of accident. The shop should occasionally be visited by the company's oculist, to serve any who may need attention.

Pleasant Surroundings.—Next to healthful conditions, pleasant surroundings are perhaps the most attractive. The largest facilities in this direction are offered in suburban districts, where enough land is obtainable for a lawn or park. In landscape gardening, large grass areas should remain unbroken, and shrubbery and flowers concentrated in masses. A pond or lagoon adds beauty by its contrast. The roofs of multi-story shops, which are usually neglected, may be turned into a roof garden or promenade, and partly covered with canvas awnings.

The building interior may be painted in pleasing colors, light green or brown being suitable for the walls, with a dado of darker shade, and cream or some warmer tint for the ceiling. White wash for this purpose is no longer favored. A limited number of mottoes or pictures on the walls are appropriate to relieve their monotony, and these may occasionally be changed or rearranged. Machinery which is enameled, or painted a nickel color, adds

greatly to the appearance and cleanliness of the shop, for when it is soiled it can easily be washed off again. In some larger printing establishments, as that of the McGraw-Hill Publishing Company, the machinery is enameled white, thus assuring cleanliness, attractiveness, and better light.

Material Benefits.—Features which result in material benefit to the workers are often most appreciated and these include co-operative or profit sharing systems, membership in insurance or mutual aid associations, and the provision of meals at cost price. Profit sharing, used by such concerns as Proctor and Gamble of Cincinnati, offer an incentive to effort, and the suggestion system used by the National Cash Register Company, and previously described, offers prizes to those who supply valuable ideas or suggestions which can be utilized. The value of this system is evident when it is considered that each trained worker is a specialist in his own line, and should know more about its details than anyone else. He should therefore be able to suggest improvements that may not have occurred to others. The system is valuable also in the sales department. Workers all become partners in the business, and instead of being a one- or two-man industry, the business may be increased to a thousand-brain-power or more, depending upon the number that are employed.

Mutual aid or fraternal associations may be organized for the benefit of a single industry, the object being to supply at least a half income for workers that are sick. Dues can be proportioned to the needs, though one-half of 1 per cent. of the regular wages is usually enough. A shop with one thousand employees would at this rate contribute $50 to $75 per week, but if more money is needed the dues can be increased, and if all is not required, collections can be temporarily suspended. Experience shows that medical service for such an association would cost about $500 per year, for there would seldom be more than three or four sick at one time.

Perhaps the greatest practical benefit that can be offered to workers is the supply of substantial hot dinners at cost price. Men bringing cold and often poorly cooked food naturally fatigue sooner than others who are better nourished. One large factory employing over 3000 persons supplies noon lunches to women at a charge of only 25 cents per week, and to men for about $1 per week, and those who must work overtime are

given evening dinner at the factory. At the Krupp works in Germany the families of the workers are allowed to unite in the company dining hall, and in some plants the dining halls overlooking a lawn or park are provided with wide verandas or balconies on which meals are served in summer. Quick lunch counters may also be maintained, and other rooms with tables and benches only for those who prefer to bring their food. Under good management the preparation of meals will require one cook and two or three assistants for every 200 persons. It would seem that many works, especially those in Europe, are vying with each other in the abundance of their altruistic measures.

Educational Measures.—Work in this direction is educational, entertaining, and a recreation. A library of books and all the magazines and journals relating to the particular business should be within reach of all, because educated minds are more efficient than others. In large works truck loads of books may be circulated through the shops during the noon hour, though it is usually best for everyone to have a walk in the open air after lunch and before returning to the afternoon's work. Technical and trade papers and journals are a great benefit to the workers and consequently to the factory owners, for individuals can seldom afford more than one or two of their own. They should, therefore be freely supplied as an important part of the shop equipment.

Evening classes and lecture courses are another means of education for those who, from lack of time and money would otherwise be without them. Large works frequently erect a separate building as a center of social and educational life for their employees, and this building may have a properly equipped auditorium for lectures and entertainments. Instruction classes may be established to any extent that interest and attendance will warrant, all such work being under the direction of the welfare manager or social secretary, though the details of management must be left to the employees. In large manufactories classes for men may be maintained in drawing, salesmanship, languages, etc., and for women in cooking, nursing, stenography, sewing, embroidery, and dancing. Lectures may be either instructive or entertaining, or both.

Recreation.—A club for recreation and entertainment may be organized, but it should be free from the works management, for

paternalism in industrial works is usually disastrous, as illustrated by the town of Pullman. Men and women working all day under the direction of others will insist on freedom of action after working hours, and while the club building may adjoin the works it should be outside of the company's property. The building may be equipped with games, pool tables, bowling alley, piano, and gymnasium. One company in Brooklyn owns and operates a building in the mountains for a summer camp, and another gives a ten days' summer outing in tents by the water to one thousand employees at a total cost of less than $6 each. Vegetable gardens in which boys and men can work and grow products for their own use have proved quite popular and are not only a source of profit to the workers, but a healthful exercise and recreation.

The suggestions given above can be modified or extended as desired, to suit the size of plant and the wishes of its occupants, and though only a few of these suggestions may be put into operation at any particular industry, some provision for the benefit and welfare of the workers should be part of all such organizations.

CHAPTER XXXII

STANDARD BUILDINGS

The following tables give standard sizes with estimated weights for typical steel-framed sheds 30 to 80 ft. in width, with clearance under the trusses of 12 to 20 ft. As the figures given are on separate units, complete estimates can readily be made on buildings of any length (Fig. 175).

The buildings are proportioned for a live load of only 30 pounds

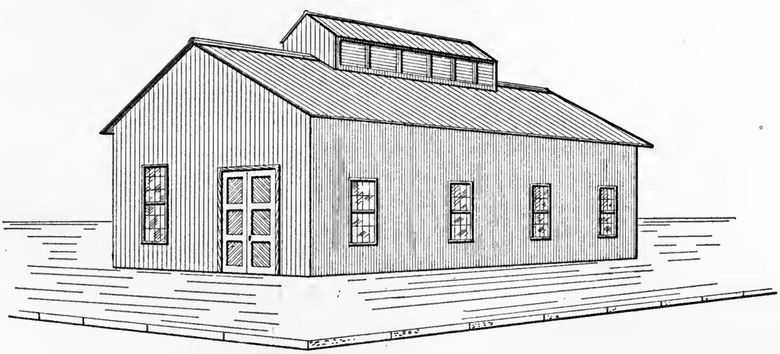


FIG. 175.—Metal covered steel framed building.

per square foot, and are especially designed for export to warm climates, but are also suitable for other places where they are for shelter and enclosure only, and not for supporting cranes, machinery, or heavy loads. Ventilators may be included or omitted as desired. The tables refer to the framing only, and do not include windows, doors, corrugated iron, louvers, or other sheet metal, nor do they include the foundations. Because of the light loads for which the framing is proportioned, they are suitable only for light covering such as corrugated iron, and not for heavy plank sheathing.

As ocean freight rates depend both on the weight and space occupied in the vessel, space is left in the tables for both kinds of data, though in many places the columns are left blank, to be filled out by the user to suit local conditions and current prices.

TABLE

MATERIAL FOR BUILDING 30′0″ WIDE

	Heights	Roof trusses	Side columns	End columns	Knee braces	Roof purlins	Side purlins	Purlin finish angles
1	12′0″	See tables	$1 < 2\frac{1}{2}\times2\times\frac{3}{16}$ 1–6″]-8 lb.	(each) 1–5″I–9.75 lb.	$2 <$s $2\frac{1}{2}\times2\times\frac{3}{16}$	$<$s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	$<$s $2\frac{1}{2}\times2\times\frac{3}{16}$	$<$ $2\frac{1}{2}\times2\times\frac{3}{16}$
2	14′0″	"	$1 < 3\times2\times\frac{1}{4}$ 1–6″]-8 lb.	1–6″I–$12\frac{1}{4}$	"	"	"	"
3	16′0″	"	$4 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	$2 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"	"
4	18′0″	"	"	1–7″ 1–15	"	"	"	"
5	20′0″	"	"	1–8″ I–18	"	"	"	"

MATERIAL FOR BUILDING 35′ 0″ WIDE

6	12′0″	"	$1 < 2\frac{1}{2}\times2\times\frac{3}{16}$ 1–6″]-8 lb.	1–5″ I	$2 <$s $2\frac{1}{2}\times2\times\frac{3}{16}$	$<$s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	$<$s $2\frac{1}{2}\times2\times\frac{3}{16}$	$<$ $2\frac{1}{2}\times2\times\frac{3}{16}$
7	14′0″	"	$1 < 3\times2\times\frac{1}{4}$ 1–6″]-8 lb.	1–6″ I	"	"	"	"
8	16′0″	"	$4 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	$2 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	$2 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"
9	18′0″	"	$4 <$s $3\times2\times\frac{1}{4}$	1–7″ I	"	"	"	"
10	20′0″	"	"	1–8″ I	"	"	"	"

MATERIAL FOR BUILDING 40′ 0″ WIDE

11	12′0″	"	$1 < 2\frac{1}{2}\times2\times\frac{3}{16}$ 1–6″]-8	1–5″ I	$2 <$s $2\frac{1}{2}\times2\times\frac{3}{16}$	4″]-5.5	$<$ $2\frac{1}{4}\times2\times\frac{1}{4}$	$<$ $3\times2\times\frac{1}{4}$
12	14′0″	"	$1 < 3\times2\times\frac{1}{4}$ 1–6″]-8 lb.	1–6″ I	"	"	"	"
13	16′0″	"	$4 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	$2 <$s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"	"
14	18′0″	"	$4 <$s: $3\times2\times\frac{1}{4}$	1–7″ I	"	"	"	"
15	20′0″	"	"	1–8″ I	"	"	"	"

XXX

× 30′0″ Long, 10 ft. Panels

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
1 Line rods: $\frac{5}{8}$″ 0	< $3 \times 2 \times \frac{1}{4}$	....	$\frac{3}{4}$″ 0 rods	$\frac{3}{4}$″ 0 rods	Pipe $2\frac{7}{8}$″ w.i.	....	< $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	1–6″]–8 lb.
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"

× 40′ 0″ Long, 10 ft. Panels

"	"	....	$\frac{3}{4}$″0 rods	$\frac{3}{4}$″0 rods	Pipe $2\frac{7}{8}$″ w.i.	....	< $2\frac{1}{2} \times 2 \times \frac{3}{16}$	1–6″]
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"
"	"	....	"	"	"	....	"	"

× 48′ 0″ Long, 12 ft. Panels

"	"	....	$\frac{3}{4}$″0 rods	$\frac{3}{4}$″0 rods	Pipe $2\frac{7}{8}$″ w.i.	<s $2\frac{1}{2} \times 2 \times \frac{3}{16}$	< $2\frac{1}{2} \times 2 \times \frac{1}{4}$	1–6″]–8 lb
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"

TABLE

MATERIAL FOR BUILDING 45′ 0″

	Heights	Roof trusses	Side columns	End columns	Knee braces	Roof purlins	Side purlins	Purlin finish angles
16	12′0″	See tables	1 < $2\frac{1}{2}\times2\times\frac{3}{16}$ 1–7″]–9.75	(each) 1–5″ I	2 < $2\frac{1}{2}\times2\times\frac{3}{16}$	4″]–5.5	<s $2\frac{1}{2}\times2\times\frac{1}{4}$	< $3\times2\times\frac{1}{4}$
17	14′0″	"	< $3\times2\times\frac{1}{4}$ 1–7″]–9.75	1–6″ I	"	"	"	"
18	16′0″	"	4 <s $3\times2\times\frac{1}{4}$	"	2 < $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"	"
19	18′0″	"	"	1–7″ I	"	"	"	"
20	20′0″	"	"	1–8″ I	"	"	"	"

MATERIAL FOR BUILDING 50′ 0″

21	12′0″	"	1 < $3\times2\times\frac{1}{4}$ 1–7″]–9.75	1–5″ I	2 <s $2\frac{1}{2}\times2\times\frac{3}{16}$	5″]–6.5	<s $3\times2\times\frac{1}{4}$	< $3\times2\times\frac{1}{4}$
22	14′0″	"	1 < $3\times2\times\frac{1}{4}$ 1–7″]–9.75	1–6″ I	"	"	"	"
23	16′0″	"	4 < $3\times2\times\frac{1}{4}$	"	2 <s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"	"
24	18′0″	"	4 < $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	1–7″ I	"	"	"	"
25	20′0″	"	"	1–8″ I	"	"	"	"

MATERIAL FOR BUILDING 55′ 0″

26	12′0″	"	4 <s $2\times2\times\frac{1}{4}$	1–5″ I	2 <s $2\frac{1}{2}\times2\times\frac{3}{16}$	5″]–6.5	<s $3\times2\times\frac{1}{4}$	< $3\times2\times\frac{1}{4}$
27	14′0″	"	4 <s $2\frac{1}{2}\times2\times\frac{1}{4}$	1–6″ I	"	"	"	"
28	16′0″	"	4 <s $3\times2\times\frac{1}{4}$	"	2 <s $2\frac{1}{2}\times2\times\frac{1}{4}$	"	"	"
29	18′0″	"	4 <s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	1–7″ I	"	"	"	"
30	20′0″	"	"	18–″ I	"	"	"	"

XXX.—*Continued*

WIDE × 48′ 0″ LONG, 12 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}''$0	< $3\times2\times\frac{1}{4}$	....	$\frac{3}{4}''$0 rods	$\frac{3}{4}''$0 rods	Pipe $3\frac{1}{2}''$ dia.	<s $2\frac{1}{2}\times2\times\frac{3}{16}$	<s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	1–6″]-8 lb.
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"
"	"	....	"	"	"	"	"	"

WIDE × 56′ 0″ LONG, 14 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}''$0	< $3\times2\times\frac{1}{4}$	2 < laced $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	$\frac{3}{4}''$0 rods	$\frac{3}{4}''$0 rods	Pipe 4″ dia.	<s $3\times2\frac{1}{2}\times\frac{1}{4}$	<s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	{ 1–7″]-9.75 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

WIDE × 56′ 0″ LONG, 14 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}''$0	< $3\times2\times\frac{1}{4}$	2 < $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	$\frac{3}{4}''$0 rods	$\frac{3}{4}''$0 rods	Pipe 4″ dia.	<s $3\times2\frac{1}{2}\times\frac{1}{4}$	<s $3\times2\times\frac{1}{4}$	1–6″]-8 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

TABLE

MATERIAL FOR BUILDING 60′ 0″

	Heights	Roof trusses	Side columns	End columns	Knee braces	Roof purlins	Side purlins	Purlin finish angles
31	12′0″	See tables	4 <s $2\frac{1}{2}\times 2\times\frac{1}{4}$	(each) 1–5″ I	2 <s $2\frac{1}{2}\times 2\times\frac{3}{16}$	1–6″]–8 lb.	< $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	< $3\times 2\times\frac{1}{4}$
32	14′0″	"	"	1–6″ I	"	"	"	"
33	16′0″	"	4 <s $3\times 2\times\frac{1}{4}$	"	2 <s $2\frac{1}{2}\times 2\times\frac{1}{4}$	"	"	"
34	18′0″	"	4 < $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	1–7″ I	"	"	"	"
35	20′0″	"	"	1–8″ I	"	"	"	"

MATERIAL FOR BUILDING 65′ 0″

36	12′0″	"	4 <s $3\times 2\times\frac{1}{4}$	1–5″ I	2 <s $2\frac{1}{2}\times 2\times\frac{1}{4}$	1–6″]–8 lb.	< $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	< $3\times 2\times\frac{1}{4}$
37	14′0″	"	"	1–6″ I	"	"	"	"
38	16′0″	"	4 <s $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	"	2 <s $3\times 2\times\frac{1}{4}$	"	"	"
39	18′0″	"	"	1–7″ I	"	"	"	"
40	20′0″	"	"	1–8″ I	"	"		"

MATERIAL FOR BUILDING 70′ 0″

41	12′0″	"	4 <s $3\times 2\times\frac{1}{4}$	1–5″ I	2 <s $3\times 2\times\frac{1}{4}$	1–6′]–8 lb.	<s $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{5}{16}$	< $3\times 2\times\frac{1}{4}$
42	14′0″	"	"	1–6″ I	45	"	"	"
43	16′0″	"	4 <s $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	"	2 <s $3\frac{1}{2}\times 2\frac{1}{2}\times\frac{1}{4}$	"	"	"
44	18′0″	"	"	1–7″ I	"	"	"	"
45	20′0″	"	"	1–8″ I	"	"	"	"

XXX.—*Continued*

WIDE × 64′ 0″ LONG, 16 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}$″0	< 3×2×¼	2 <s 3×2×¼	¾″0 rods	¾″0 rods	Pipe 4½″ dia.	<s 3½×2½×¼	<s 3½×2½×¼	1-6″]-8 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

WIDE × 64′ 0″ LONG, 16 FT. PANELS

$\frac{5}{8}$″0	< 3×2×¼	2 < 3×2×¼	¾″0 rods	¾″0 rods	Pipe 4½″ dia.	<s 3½×2½×¼	<s 3½×2½×¼	{ 1-7″]-9.75 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

WIDE × 72′ 0″ LONG, 18 FT. PANELS

$\frac{5}{8}$″0 rods	< 3×2×¼	2 < 3×2×¼	¾″0 rods	¾″0 rods	Pipe 5″ dia.	<s 3½×2½×¼	<s 3×2×¼	1-6″]-8 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

TABLE

MATERIAL FOR BUILDING 75′ 0″

	Heights	Roof trusses	Side columns	End columns	Knee braces	Roof purlins	Side purlins	Purlin finish angles
46	12′0″	See tables	4 <s $3\times2\times\frac{1}{4}$	(each) 1–5″ I	2 <s $3\times2\times\frac{1}{4}$	1–6″]–8 lb.	<s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{5}{16}$	< $3\times2\times\frac{1}{4}$
47	14′0	"	"	1–6″ I	"	"	"	"
48	16′0″	"	4 <s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	"	2 <s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	"	"	"
49	18′0″	"	"	1–7″ I	"	"	"	"
50	20′0″	"	"	1–8″ I	"	"	"	"

MATERIAL FOR BUILDING 80′ 0″

	Heights	Roof trusses	Side columns	End columns	Knee braces	Roof purlins	Side purlins	Purlin finish angles
51	12′0″	"	4 <s $3\times2\times\frac{1}{4}$	1–5″ I	2 <s $3\times2\times\frac{1}{4}$	1–6″]–8 lb.	< $3\frac{1}{2}\times2\frac{1}{2}\times\frac{5}{16}$	<s $3\times2\times\frac{1}{4}$
52	14′0″	"	"	1–6″ I	"	"	"	"
53	16′0″	"	4 <s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	"	2 <s $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$	"	"	"
54	18′0″	"	"	1–7″ I	"	"	"	"
55	20′0″	"	"	1–8″ I	"	"	"	"

XXX.—*Continued*

WIDE × 72′ 0″ LONG, 18 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}$″0 rods	< $3 \times 2 \times \frac{1}{4}$	2 <s $3 \times 2 \times \frac{1}{4}$	$\frac{3}{4}$″0 rods	$\frac{3}{4}$″0 rods	Pipe 5″ dia.	<s $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	<s $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	1-6″]-8 lb.
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"	"

WIDE × 72′ 0″ LONG, 18 FT. PANELS

Purlin ties	Purlin clips	Eave strut at ends	Bracing between rafters	Long'l bracing	Long'l struts	Bracing on tie beams	End purlins	End rafters
$\frac{5}{8}$″0 rods	< $3 \times 2 \times \frac{1}{4}$	2 <s $3 \times 2 \times \frac{1}{4}$	$\frac{3}{4}$″0 rods	$\frac{3}{4}$″0 rods	Pipe 5″ dia.	<s $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	<s $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	1-7″]-9.75 lb.
"		"	"	"	"	"	"	"
"		"	"	"	"	"	"	"
"		"	"	"	"	"	"	"
"		"	"	"	"	"	"	"

TABLE XXXI

ROOF TRUSSES

Live Load per square foot = 30 lb.
Material—Steel, Factor of safety = 4.
Allowed tension = $7\frac{1}{2}$ tons per square inch
Allowed compression = 6 tons per square inch
Pitch of roof = 6 in. to 1 ft. 0 in.

Weights are in pounds
Measurements in cubic feet
Prices are for material delivered alongside steamer at New York City.

Span out to out of walls or posts	Distance between trusses														
	10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	625	22	......	630	22	......	650	22	......	650	22	......	....	....	......
35	800	28	......	800	28	......	860	28	......	860	28	......	....	....	......
40	1,000	34	......	1,000	34	......	1,140	34	......	1,206	34	......	....	....	......
45	1,200	40	......	1,250	40	......	1,380	40	......	1,400	40	......	....	....	......
50	....	....	......	1,550	45	......	1,580	45	......	1,660	45	......	1,860	45	......
55	....	....	......	1,780	51	......	1,750	51	......	1,985	51	......	2,125	51	......
60	....	....	......	1,950	57	......	2,080	57	......	2,350	57	......	2,500	57	......
65	....	....	......	2,250	63	......	2,500	63	......	2,635	63	......	2,850	63	......
70	....	....	......	2,850	69	......	2,800	69	......	2,820	69	......	3,360	69	......
75	....	....	......	3,060	74	......	3,100	74	......	3,420	74	......	4,075	74	......
80	....	....	......	3,210	80	......	3,600	80	......	3,700	80	......	4,350	80	......

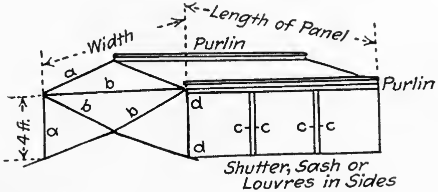


TABLE XXXII

ONE PANEL OF MONITOR FRAMING

As an approximate guide for proper sizes of monitors to use note the following sizes
For roof spans of 30 ft. to 35 ft. use monitor 6 ft. wide
For roof spans of 40 ft. to 50 ft. use monitor 8 ft. wide
For roof spans of 55 ft. to 65 ft. use monitor 10 ft. wide
For roof spans of 70 ft. to 80 ft. use monitor 12 ft. wide

Note.—In every case where a monitor is used the following items must be added to the amounts given in the table:
For monitor 6 ft. wide add .... lb. .... cu. ft. .... dollars
For monitor 8 ft. wide add .... lb. .... cu. ft. .... dollars
For monitor 10 ft. wide add .... lb. .... cu. ft. .... dollars
For monitor 12 ft. wide add .... lb. .... cu. ft. .... dollars

Weights are given in pounds, measurement in cubic feet.
Prices are in dollars for material delivered alongside steamer in New York City.

Size of Material:
For monitor 6 ft. wide $a = 2 \angle\; 2\frac{1}{2} \times 2 \times \frac{3}{16}$
For monitor 8 ft. wide $a = 2 \angle\; 2\frac{1}{2} \times 2 \times \frac{1}{4}$
For monitor 10 ft. wide $a = 2 \angle\; 3 \times 2 \times \frac{1}{4}$
For monitor 12 ft. wide $a = 2 \angle\; 3 \times 2\frac{1}{2} \times \frac{1}{4}$
$b = 1 \angle\; 2 \times 2 \times \frac{3}{16}$, $c = 1 \angle\; 2 \times 2 \times \frac{3}{16}$, $d = 1 \angle\; 2\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$

Note.—The purlins included in this table are the two extra lines required where monitors are used.

Width of monitor	Classification	Distance between trusses (or panel length)														
		10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
		Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
6	Shop	510	....		550	....		590	....		630	....	......	610	....	
	Purlins	110	....	$28.80	130	......	$36.00	180	....	$40.80	260	....	......	290	....	$50.50
8	Shop	560	....		600	....		640	....		680	....	......	720	....	
	Purlins	110	....	32.50	130	....	38.80	180	....	43.40	260	....	......	290	....	53.50
10	Shop	600	....		640	....		680	....		720	....	......	790	....	
	Purlins	110	....	37.60	130	....	40.80	180	....	46.30	260	....	......	290	....	56.00
12	Shop	680	....		720	....		760	....		800	....	......	840	....	......
	Purlins	110	....	41.80	130	....	45.00	180	....	49.70	260	....	......	290	....	60.00

TABLE XXXIII

SIDE POSTS AND KNEE BRACES

Weights are in pounds for 1 post and 1 knee brace. Measurements are in cubic feet. Prices alongside steamer, New York City

Span, feet	Distance between trusses	Height of Posts														
		12 ft.			14 ft.			16 ft.			18 ft.			20 ft.		
		Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	10–12–14	400	18	......	450	20	......	500	25	......	550	25	......	575	28	......
	16	400	18	......	450	20	......	500	25	......	550	25	......	575	28	......
35	10–12–14	400	18	......	450	20	......	500	25	......	600	25	......	630	28	......
	16	400	24	......	450	27	......	500	29	......	600	33	......	630	36	......
40	10–12–14	400	18	......	450	20	......	500	25	......	600	25	......	630	28	......
	16	450	24	......	500	27	......	550	29	......	600	33	......	630	36	......
45	10–12–14	450	24	......	500	27	......	550	29	......	600	33	......	630	36	......
	16	450	24	......	500	27	......	550	29	......	600	33	......	630	36	......
50	12–14	450	24	......	500	27	......	550	29	......	700	33	......	730	36	......
	16–18	550	31	......	600	35	......	650	40	......	700	45	......	730	49	......
55	12–14	450	31	......	500	27	......	550	29	......	700	33	......	730	36	......
	16–18	550	31	......	600	35	......	650	40	......	700	45	......	730	49	......

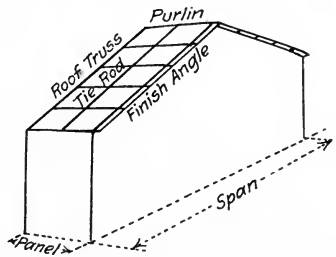
TABLE XXXIII.—*Continued*

SIDE POSTS AND KNEE BRACES

Weights are in pounds for 1 post and 1 knee brace. Measurements are in cubic feet. Prices alongside steamer, New York City

Span, feet	Distance between trusses	Height of Posts														
		12 ft.			14 ft.			16 ft.			18 ft.			20 ft.		
		Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
60	12–14	550	31	......	600	35	......	650	40	......	700	45	......	730	49	......
	16–18	550	31	......	600	35	......	650	40	......	700	45	......	730	49	......
65	12–14	550	31	......	600	35	......	650	40	......	700	45	......	730	49	......
	16–18	550	31	......	600	35	......	650	40	......	800	45	......	850	49	......
70	12–14	550	31	......	600	35	......	650	40	......	800	45	......	850	49	......
	16–18	550	31	......	600	35	......	650	40	......	800	45	......	850	49	......
75	12–14	550	31	......	600	35	......	650	40	......	800	45	......	850	49	......
	16–18	650	31	......	700	35	......	750	40	......	800	45	......	850	49	......
80	12–14	550	31	......	600	35	......	650	40	......	800	45	......	850	49	......
	16–18	650	31	......	700	35	......	750	40	......	800	45	......	850	49	......

TABLE XXXIV

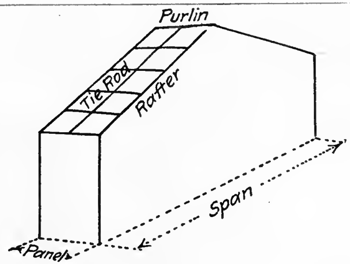


One End Panel of Roof Purlins

This table includes the purlin, tie rods, purlin clips, finish angle and connections
The spacing of purlins is 5 ft. 6 in.
The size of purlins used is as follows:
For panel lengths of 10 ft. use $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$
For panel lengths of 12 ft. use 4 in.]s 5.5 lb. per foot
For panel lengths of 14 ft. use 5 in.]s 6.5 lb. per foot
For panel lengths of 16 ft. use 6 in.]s 8.0 lb. per foot
For panel lengths of 18 ft. use 6 in.]s 8.0 lb. per foot
Finish $< 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$. Tie rods $\frac{5}{8}''$
Weights are in pounds. Measurements in cubic feet. Prices are for material delivered alongside steamer at New York City.

Span out to out of walls or posts	Distance between trusses (or panel length)														
	10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	696	....	......	835	....	......	1,040	....	......	1,350	....	......	....	....	......
35	840	....	......	1,035	....	......	1,300	....	......	1,680	....	......	....	....	......
40	865	....	......	1,060	....	$22.50	1,320	....	......	1,705	....	......	....	....	......
45	1,037	....	......	1,240	....	......	1,555	....	......	2,015	....	......	....	....	......
50	....	....	......	1,275	....	......	1,590	....	$32.60	2,050	....	......	2,145	....	......
55	....	....	......	1,465	....	......	1,835	....	......	2,365	....	......	2,595	....	......
60	....	....	......	1,510	....	......	1,880	....	......	2,410	....	$48.50	2,640	....	......
65	....	....	......	1,710	....	......	2,140	....	......	2,750	....	......	3,020	....	......
70	....	....	......	1,740	....	......	2,170	....	......	2,780	....	......	3,050	....	$61.50
75	....	....	......	1,935	....	......	2,400	....	......	3,100	....	......	3,400	....	......
80	....	....	......	1,970	....	......	2,430	....	......	3,150	....	......	3,430	....	......

TABLE XXXV



ONE INTERMEDIATE PANEL OF ROOF PURLINS

The table includes tie rods and clips necessary for one panel. Purlins are spaced 5′6″ apart c to c.
The size of purlins used is as follows:

For panel length of 10 ft. use $3\frac{1}{2}\times2\frac{1}{2}\times\frac{1}{4}$ <
For panel length of 12 ft. use 4 in.]s 5.5 lb. per foot
For panel length of 14 ft. use 5 in.]s 6.5 lb. per foot
For panel length of 16 ft. use 6 in.]s 8.0 lb. per foot
For panel length of 18 ft. use 6 in.]s 8.0 lb. per foot

Tie rods are 5/8 in. diameter. Weights are in pounds. Measurements in cubic feet. Prices are for material delivered alongside steamer at New York City. Capacity of purlins 20 lb. per square foot.

Span out to out of walls or posts	Distance between trusses (or panel length)														
	10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	455	....	......	590	....	......	790	....	......	1,085	....	......	....	....	......
35	562	....	......	732	....	......	982	....	......	1,352	....	......	....	....	......
40	570	....	......	740	....	......	990	....	......	1,360	....	......	....	....	......
45	680	....	......	885	....	......	1,185	....	......	1,628	....	......	....	....	......
50	....	....	......	890	....	......	1,190	....	......	1,635	....	......	1,830	....	......
55	....	....	......	1,030	....	......	1,385	....	......	1,905	....	......	2,125	....	......
60	....	....	......	1,035	....	......	1,395	....	......	1,915	....	......	2,135	....	......
65	....	....	......	1,185	....	......	1,585	....	......	2,175	....	......	2,445	....	......
70	....	....	......	1,195	....	......	1,595	....	......	2,184	....	......	2,456	....	......
75	....	....	......	1,335	....	......	1,785	....	......	2,465	....	......	2,745	....	......
80	....	....	......	1,345	....	......	1,795	....	......	2,475	....	......	2,755	....	......

TABLE XXXVI

Ends of Buildings.

Diagrams showing General Construction,
Pitch, 6" to 12".

The Sketches shown are for a Height of 20' to Eave Line. For Heights of 16' and under, use one less Line of Purlins than shown on Sketches.

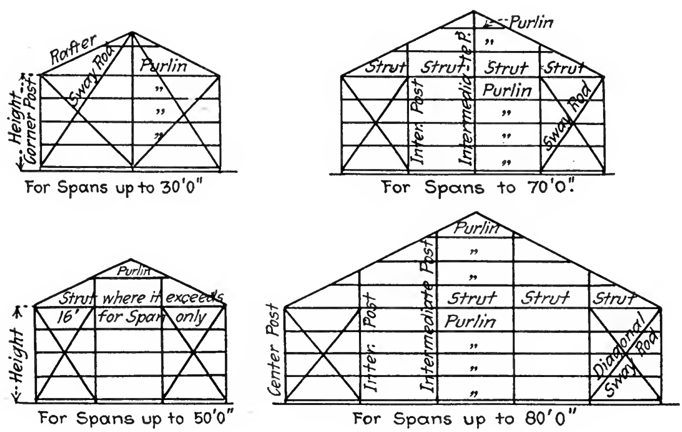


TABLE XXXVII.—ENDS OF BUILDINGS

Weights in pounds. Measurements in cubic feet. Prices alongside steamer in N. Y.
This table includes corner posts. Add for 1 door not exceeding 25 sq. ft. area. ......lb. ......cu. ft. ......dollars
Add for 1 window not exceeding 25 sq. ft. area. ......lb. ......cu. ft. ......dollars

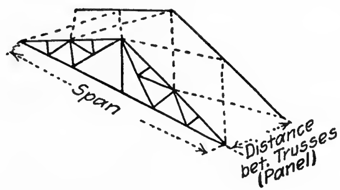
Span in feet	Classi-fication	Height														
		12 ft.			14 ft.			16 ft.			18 ft.			20 ft.		
		Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	Shop	1800			2000			2100			2280			2500		
	Purlins	650	65	......	650	73	......	650	80	......	800	89	......	800	95	......
35	Shop	2050			2270			2460			2730			3050		
	Purlins	650	69	......	650	78	......	650	86	......	800	95	......	800	104	......
40	Shop	2245			2475			2650			2920			3240		
	Purlins	830	68	......	830	79	......	830	89	......	1000	99	......	1000	109	......
45	Shop	2335			2580			2750			3030			3350		
	Purlins	1000	68	......	1150	80	......	1150	91	......	1400	103	......	1400	115	......
50	Shop	2540			2780			2920			3900			4200		
	Purlins	1300	70	......	1500	89	......	1500	101	......	1550	113	......	1500	126	......

TABLE XXXVII.—ENDS OF BUILDINGS.—*Continued.*

Weight in pounds. Measurements in cubic feet. Prices alongside steamer in N. Y.
This table includes corner posts. Add for 1 door not exceeding 25 sq. ft. area. ......lb. ......cu. ft. ......dollars
Add for 1 window not exceeding 25 sq. ft. area. ......lb. ......cu. ft. ......dollars

Span in feet	Classification	Height 12 ft. Weight	12 ft. Meas't	12 ft. Price	14 ft. Weight	14 ft. Meas't	14 ft. Price	16 ft. Weight	16 ft. Meas't	16 ft. Price	18 ft. Weight	18 ft. Meas't	18 ft. Price	20 ft. Weight	20 ft. Meas't	20 ft. Price
55	Shop	2750			3720			3880			4270			4720		
	Purlins	1300	84	......	1050	98	......	1050	111	......	1300	124	......	1300	137	......
60	Shop	3620			3960			4130			4530			5100		
	Purlins	1300	104	......	1300	117	......	1300	129	......	1600	142	......	1600	155	......
65	Shop	4010			4350			4540			4960			5450		
	Purlins	1725	123	......	1725	136	......	1725	147	......	2100	160	......	2100	172	......
70	Shop	4330			4620			4800			5310			5800		
	Purlins	1900	142	......	1900	154	......	1900	166	......	2300	178	......	2300	190	......
75	Shop	4580			5010			5220			5770			6400		
	Purlins	1500	151	......	1700	163	......	1700	176	......	2100	188	......	2100	200	......
80	Shop	4830			5270			5470			6000			6540		
	Purlins	2450	160	......	2450	172	......	2450	185	......	2900	197	......	2900	210	......

TABLE XXXVIII



Bracing Between Rafters

The bracing is shown by the dotted lines on sketch and consists of $\frac{3}{4}''$ round rods.
Where the building is subdivided into 3 or 4 panels put bracing in one panel.
Where subdivided into 5 or 6 panels, use bracing in 2 panels.
Where subdivided into 7 or 8 panels, use bracing in 3 panels.
Where subdivided into 9 or 10 panels; use bracing in 3 panels.
Where subdivided into 11 or 12 panels, use bracing in 4 panels.
Where subdivided into 13 or 14 panels, use bracing in 5 panels.
Weights are in pounds for 1 panel, measurements in cubic feet. Prices are alongside steamer N. Y.

Span in feet	Distance between trusses (or panel length)														
	10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	210	......	......	238	......	......	250	......	......	260	......	......	......	......	......
35	330	......	......	340	......	......	370	......	......	375	......	......	......	......	......
40	391	......	......	410	......	......	425	......	......	446	......	......	......	......	......
45	420	......	......	421	......	......	440	......	......	456	......	......	......	......	......
50	......	......	......	433	......	......	450	......	......	470	......	......	483	......	......
55	......	......	......	448	......	......	461	......	......	478	......	......	495	......	......
60	......	......	......	467	......	......	475	......	......	488	......	......	508	......	......
65	......	......	......	......	......	......	......	......	......	......	......	......	518	......	......
70	......	......	......	......	......	......	......	......	......	......	......	......	528	......	......
75	......	......	......	......	......	......	......	......	......	......	......	......	538	......	......
80	......	......	......	......	......	......	......	......	......	......	......	......	548	......	......

TABLE XXXIX

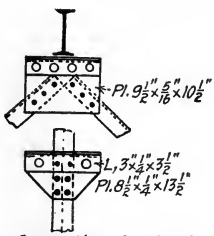
BRACING IN PLANE OF TIE BEAMS BETWEEN END FRAME AND ADJACENT TRUSS

The weights and measurements include all connections.
Weights are in pounds. Measurements in cubic feet. Prices are in dollars, alongside steamer at New York City.

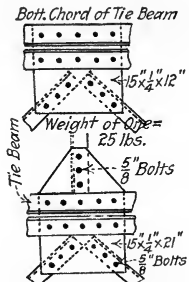
Span out to out of walls and posts	Distance between End Frame and Truss														
	10 ft.			12 ft.			14 ft.			16 ft.			18 ft.		
	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price	Weight	Meas't	Price
30	315	....	......	330	....	......	360	....	......	465	....	......	515	....	......
35	455	....	......	500	....	......	550	....	......	705	....	......	790	....	......
40	480	....	......	520	....	......	675	....	......	765	....	......	910	....	......
45	490	....	......	530	....	......	685	....	......	770	....	......	920	....	......
50	505	....	......	545	....	......	695	....	......	775	....	......	930	....	......
55	645	....	......	815	....	......	880	....	......	1065	....	......	1245	....	......
60	660	....	......	825	....	......	900	....	......	1075	....	......	1255	....	......
65	670	....	......	840	....	......	910	....	......	1090	....	......	1270	....	......
70	685	....	......	855	....	......	925	....	......	1100	....	......	1280	....	......
75	905	....	......	985	....	......	1190	....	......	1190	....	......	1585	....	......
80	920	....	......	1000	....	......	1200	....	......	1300	....	......	1600	....	......

TABLE XL

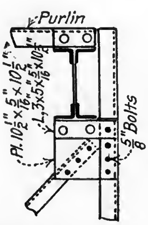
Details and Weights of Connections for Bracing between Trusses at Tie Beams, and Posts to Tie Beams.
Note.—The Weights given include only the Weights of Material for which sizes are given in the Details, and the Measurements, etc., for the same.



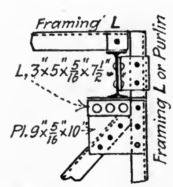
Connection for Bracing between Tie Beams to Inter. Posts of End Frame.
Weight of One = 30 lbs.



Weight of One = 28 lbs.



Connection to Posts of 4 Ls, Latticed, at Corner of End Frame.
Weight of One = 22 lbs.



Connection for Bracing between Tie Beams to Corner Posts of End Frame; if Posts are I Beams.
Weight of One = 19 lbs.

Connected to Inter. Posts of End Frame where a Latticed Strut extends across the End at Eaves.
Weight of One = 17 lbs.

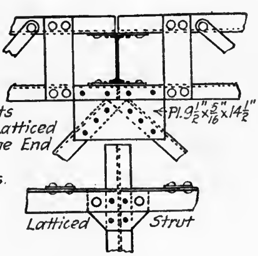


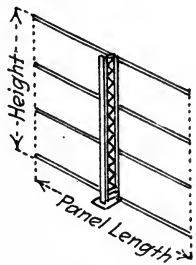
TABLE XLI.—MATERIAL FOR SIDE POSTS

Span, ft.	Distance between trusses					Heights
	10 ft.	12 ft.	14 ft.	16 ft.	18 ft.	
30	4 <s 2″×2½″×¼″	4 <s 2″×2½″×¼″	4 <s 2″×2½″×¼″	4 <s 2″×2½″×¼″	....	12–14–16
	"	"	"	"	....	18–20
35	"	"	"	"	....	12–14–16
	4 <s 3″×2″×¼″	4 <s 3″×2″×¼″	4 <s 3″×2″×¼″	4 <s 3″×2″×¼″	....	18–20
40	4 <s 2″×2½″×¼″	4 <s 2″×2½″×¼″	4 <s 2″×2½″×¼″	"	....	12–14–16
	4 <s 3″×2″×¼″	4 <s 3″×2″×¼″	4 <s 3″×2″×¼″	"	....	18–20
45	"	"	"	"	....	12–14–16
	4 <s 3″×2″×¼″	"	"	"	....	18–20
50	....	"	"	4 <s 3½″×2½″×¼″	4 <s 3½″×2½″×¼″	12–14–16
	....	4 <s 3½″×2½″×¼″	4 <s 3½″×2½″×¼″	"	"	18–20
55	....	4 < 3×2×¼	4 <s 3×2×¼	"	"	12–14–16
	....	4 < 3½×2½×¼	4 <s 3½×2½×¼	"	"	18–20

TABLE XLI.—MATERIAL FOR SIDE POSTS.—*Continued*

Span, ft.	Distance between trusses					Heights
	10 ft.	12 ft.	14 ft.	16 ft.	18 ft.	
60	....	"	"	"	"	12–14–16
	....	"	"	"	"	18–20
65	....	"	"	"	"	12–14–16
	....	"	"	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	18–20
70	....	"	"	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	12–14–16
	....	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	18–20
75	....	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	"	"	12–14–16
	....	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	"	"	18–20
80	....	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	"	"	12–14–16
	....	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	$4 < 3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	"	"	18–20

TABLE XLII



Purlins on Sides of Building

Weights are given in pounds and include connections to posts. Measurements are in cubic feet. Prices are for material delivered alongside steamer at N. Y. City. Discount, ——.

For the framing necessary for one window in each panel add 110 lb., —— cu. ft., —— dollars.

For the framing necessary for one door not exceeding 25 sq. ft. area, add 280 lb., —— cu. ft., —— dollars.

For heights of 12 ft. to 18 ft. use 4 lines of purlins.

For heights of 18 ft. to 20 ft. use 5 lines of purlins.

Length of panel	Height														
	20 ft.			18 ft.			16 ft.			14 ft.			12 ft.		
	W't	Meas't	Price	W't	Meas't	Price	W't	Meas't	Price	W't	Meas't	Price	W't	Meas't	Price
10′ 0″	Ang's, $2\times2\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\times2\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\times2\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\times2\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\times2\frac{1}{2}\times\frac{1}{4}$		
	206	....	3.60	206	....	3.60	170	....	3.07	170	....	3.07	170	....	3.07
12′ 0″	Ang's, $2\times3\times\frac{1}{4}$			Ang's, $2\times3\times\frac{1}{4}$			Ang's, $2\times3\times\frac{1}{4}$			Ang's, $2\times3\times\frac{1}{4}$			Ang's, $2\times3\times\frac{1}{4}$		
	266	....	4.78	266	....	4.78	217	....	3.90	220	....	3.90	200	....	3.60
14′ 0″	Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{4}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{1}{4}$		
	362	....	6.50	362	....	6.50	294	....	5.40	300	....	5.40	250	....	4.50
16′ 0″	Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{16}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{16}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{16}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{16}$			Ang's, $2\frac{1}{2}\times3\frac{1}{2}\times\frac{5}{16}$		
	508	....	9.15	508	....	9.15	410	....	7.38	410	....	7.38	340	....	6.12
18′ 0″	Ang's, $3\times4\times\frac{5}{16}$			Ang's, $3\times4\times\frac{5}{16}$			Ang's, $3\times4\times\frac{5}{16}$			Ang's, $3\times4\times\frac{5}{16}$			Ang's, $3\times4\times\frac{5}{16}$		
	660	....	11.88	650	....	11.88	640	....	9.72	540	....	9.72	460	....	8.28

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